SCIENTIFIC AMERICAN SUPPLEMENT No. 865

Scientific American Supplement, Vol. XXXIV. No. 865.
Scientific American, established 1845.

NEW YORK, JULY 30, 1892.

Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.

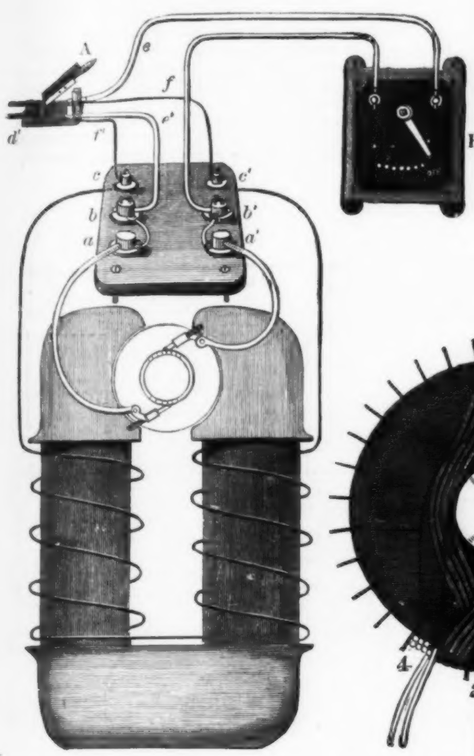


FIG. 4.—MOTOR CONNECTIONS.

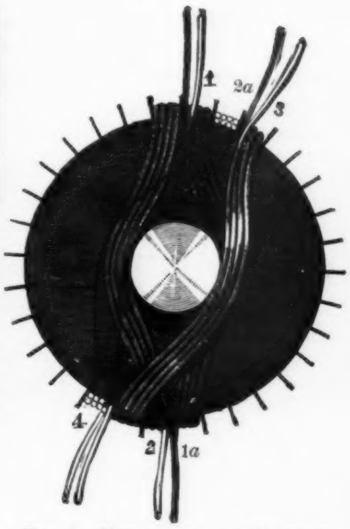


FIG. 2.—BEGINNING OF WINDING.

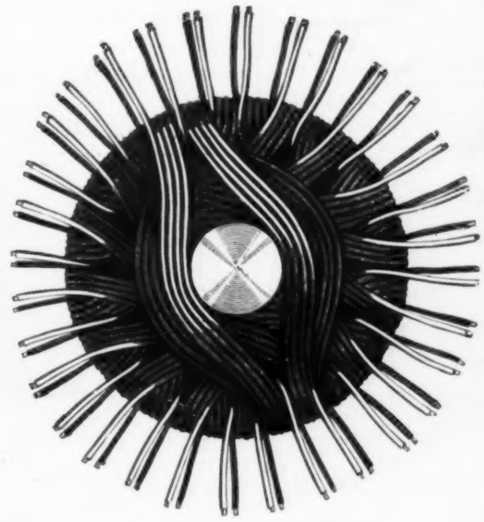


FIG. 3.—END OF WINDING.

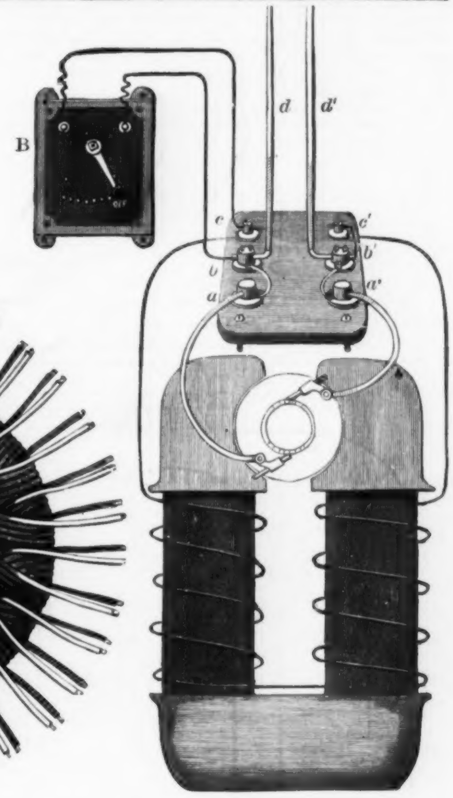
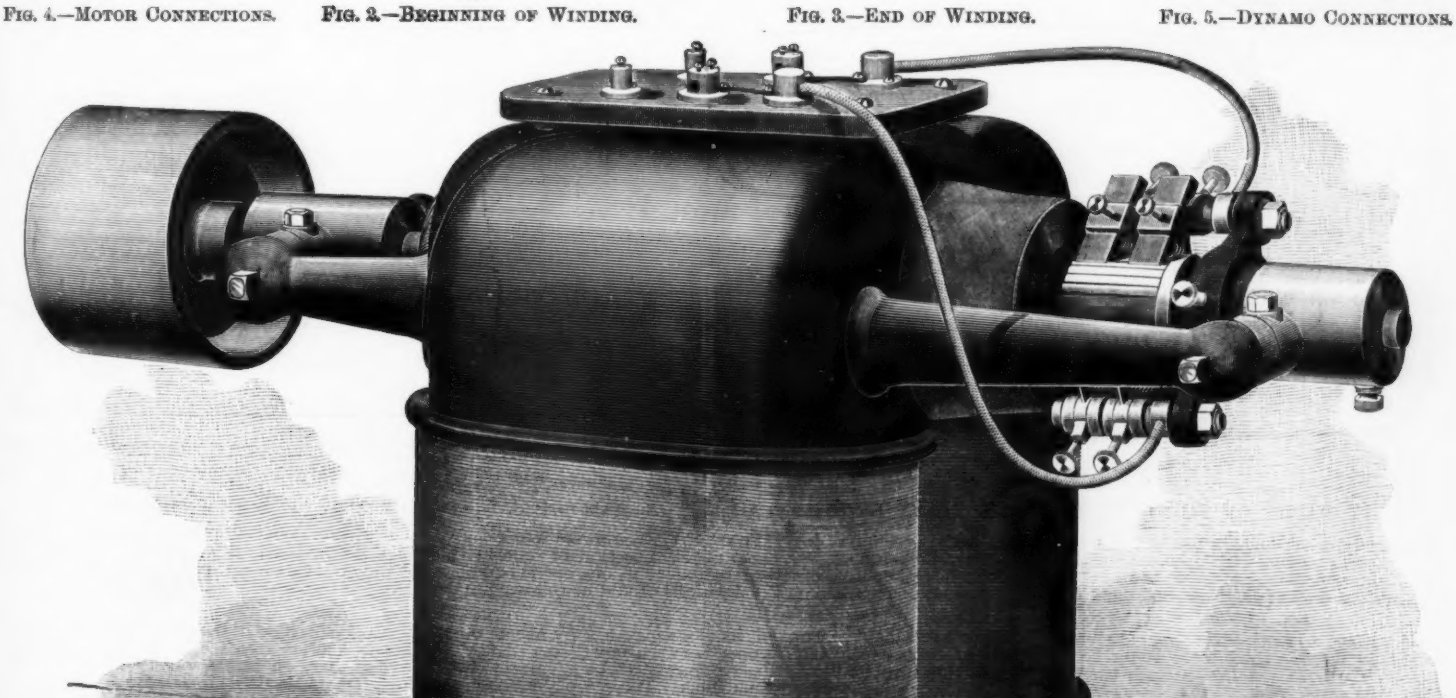


FIG. 5.—DYNAMO CONNECTIONS.



SCIENTIFIC AMERICAN DYNAMO AND MOTOR.

THE SCIENTIFIC AMERICAN DYNAMO.

ACCORDING to a promise given several times in the Notes and Queries columns of the SCIENTIFIC AMERICAN, we now present our readers with an illustrated description of a plain shunt-wound dynamo of simple construction, capable of supplying a current of from 60 to 75 110-volt incandescent lamps, or of being used as a 5 horse power motor.

This machine was constructed especially for the benefit of the readers of the SCIENTIFIC AMERICAN, by Mr. W. S. Bishop, of New Haven, Conn. It was designed to meet the wants of mechanics and amateurs who desire to construct a simple dynamo or motor for their own use, but who do not care to enter into the matter scientifically.

Now, although this course may enable many to make a fairly practical machine, while possibly a few may chance to build machines equal to those from the best makers, we recommend a thorough study of the principles involved in the construction and operation of dynamos and motors, before proceeding with the mechanical work. There are many good books on this subject, and there is now no excuse for ignorance in electrical matters.

The machine, as will be seen in the perspective view, is vertical, the polar extremities of the field magnet being uppermost, the journals of the armature being supported by arms thrown out from the sides of the field magnet.

The yoke is a single casting, which is planed on its upper surface to receive the squared ends of the arms of the field magnet; these arms being fastened to the yoke by tap bolts passing through the yoke into the ends of the arms.

The waists of the field magnet are slightly thicker at the middle than at the edges; this form being given to facilitate the winding. To the arms of the field magnets are fitted oblong spools of heavy paper or pasteboard, and to these spools is fitted a hardwood mandrel, which is able to resist the pressure of the wire wound upon the spools. The winding is done in a lathe, the mandrel being revolved slowly to admit of careful work.

The dimensions of the field magnet are tabulated below:

Total height of field magnet	20 5/16	in.
Width	12	"
Height of polar extremity above winding	6¼	"
Height of waist	9½	"
Thickness at the center	4½	"
Thickness of yoke	4½	"
Diameter of bore of polar extremities	5⅛	"
Diameter of armature, about	5	"
Length of arms for supporting the journal boxes of armature shaft, commutator end	9¾	"
Pulley end	5⅜	"

The principal dimensions of the armature are tabulated below:

Length of armature shaft	36½	in.
Largest diameter of shaft	1⅜	"
Diameter of portion inclosed in armature core	1¼	"
Diameter of bearings	1 1/32	"
Length of armature core	11	"
Diameter of armature core	4¼	"
Diameter of pulley	6	"
Face of pulley	5	"
Length of journal boxes	4⅝	"

The details of the winding are given below:

The field magnet is wound with No. 18 Brown & Sharpe gauge single-covered magnet wire 12 layers deep, the inner ends of the two coils being connected with each other, the outer ends being connected with the commutator brushes. The armature is wound with No. 12 Brown & Sharpe gauge double-covered magnet wire, 32 coils, with 8 convolutions in each coil. There are approximately 22 ft. of wire in each coil. Weight of wire on armature 17 pounds, on field magnet 52 pounds. The machine, when run at 1,450 revolutions a minute, generates a current of 35 amperes, the electromotive force being 110 volts. When the machine is used as a motor 1⅛ amperes are consumed in the field magnet, and when the machine is running light only 1 ampere is consumed in the armature.

The armature core is built up of sheet iron disks 4¼ inches in diameter, with a central aperture 1¼ inches in diameter. These disks are separated by sheets of tissue paper, and clamped between end plates. They are insulated from the armature shaft by a vulcanized fiber tube ⅛ of an inch thick. The end plates which clamp the soft iron disks, and also a central thick plate located at the mid-length of the armature core, have 32 radial slits in their peripheries for receiving the wedges which separate the different armature coils. One of the end plates rests against a shoulder on the armature shaft, and is prevented from turning by a key. The other end plate is also prevented from turning on the shaft by a key, and is pressed against the disks by a nut turned on the threaded portion of the shaft. The thick disk at the center of the armature core is prevented from turning by a pin driven in a hole drilled diagonally through the armature core, the central disk and the shaft.

The armature winding is done according to the system illustrated in Figs. 2 and 3. In this case the winding of the first coil begins in space 1, is carried around through space 1a until the coil is complete.

The armature is turned half way over, and beginning in space 2 for the second coil, the winding is carried around in the same manner, leaving the beginning and the ending of the coil in the same place and upon the same side of the armature. The armature is again reversed and the third coil is begun in space 3, leaving the intermediate space 2a. When coil 3 is complete, the fourth coil is begun in space 4, on the opposite side of the armature, and carried through space 2a. The armature is again reversed and the operation of winding is carried on in the same order, leaving a space between alternate coils upon one side of the armature. It is advisable to place mica between the different coils where they cross at opposite ends of the armature, to prevent the possibility of a cross or short circuit.

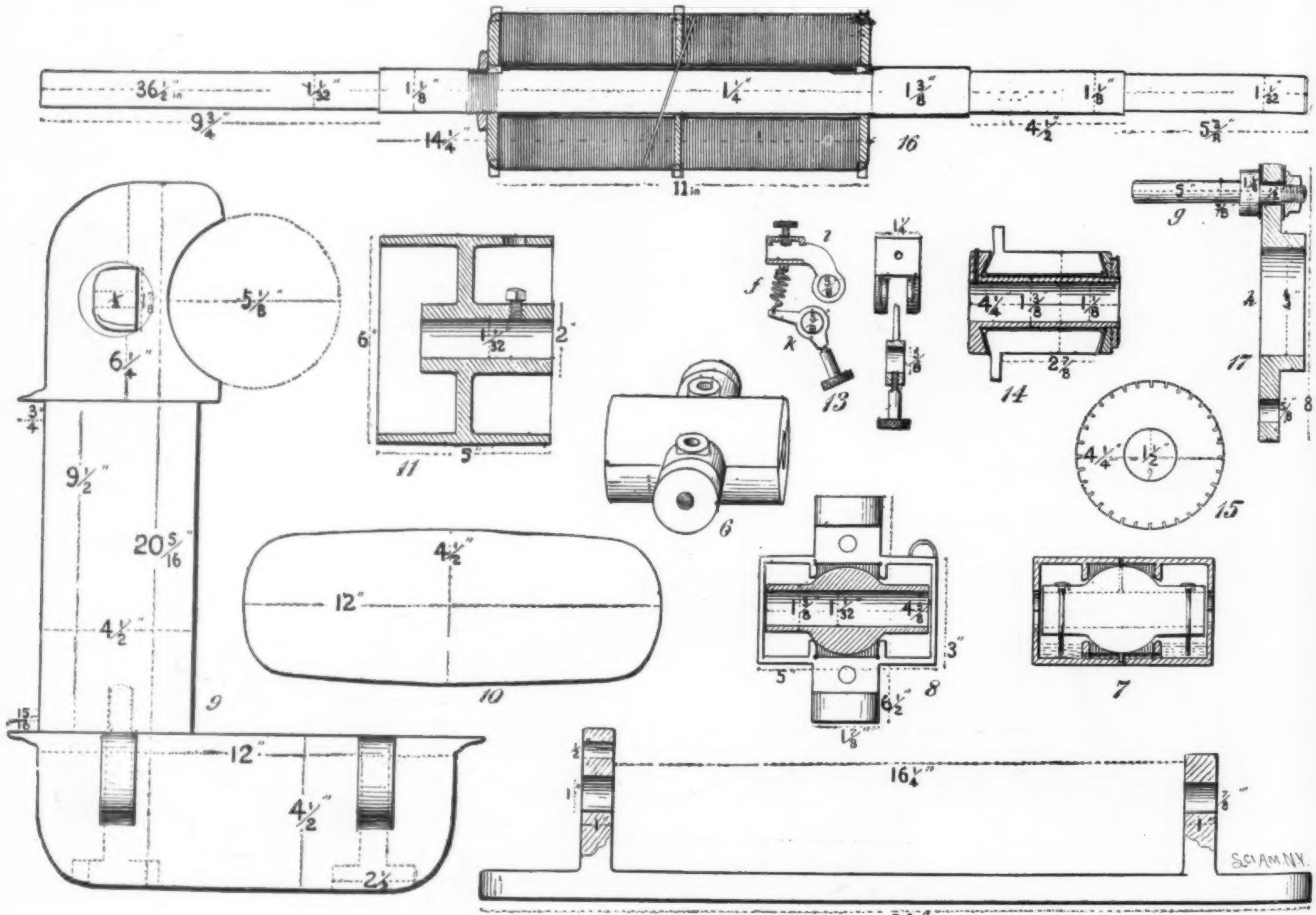
The commutator, which is of ordinary construction, has thirty-two bars and is made according to the plan already given in the SCIENTIFIC AMERICAN, also in SUPPLEMENT 600. The terminals of the coils are connected with the commutator bars in the same manner as those of the Siemens machine several times described in these columns, that is to say, the beginning of one coil and the end of the preceding coil are connected to the same bar of the commutator. This order is preserved throughout.

The journal boxes of the armature shaft are supported between arms projecting from the sides of the field magnet. They consist of an outer brass shell and an inner bronze portion fitted to the journal box by means of a ball and socket joint, the inner portion being provided with a spherical central boss, which is babbitted in the cast iron outer part held by the arms.

The bronze portion of the box in which the armature shaft revolves is slotted transversely across the top to a point below the upper surface of the shaft, and rings dropped into these slots rest upon the shaft and dip into the oil contained in the reservoir in the lower part of the box, as shown in Fig. 7. As the shaft revolves, these rings carry up a small amount of oil which keeps the bearings continually lubricated.

It will be seen that by the construction of the boxes they are able to swing in two planes at right angles to each other, and they are thus enabled to adapt themselves automatically to the armature shaft.

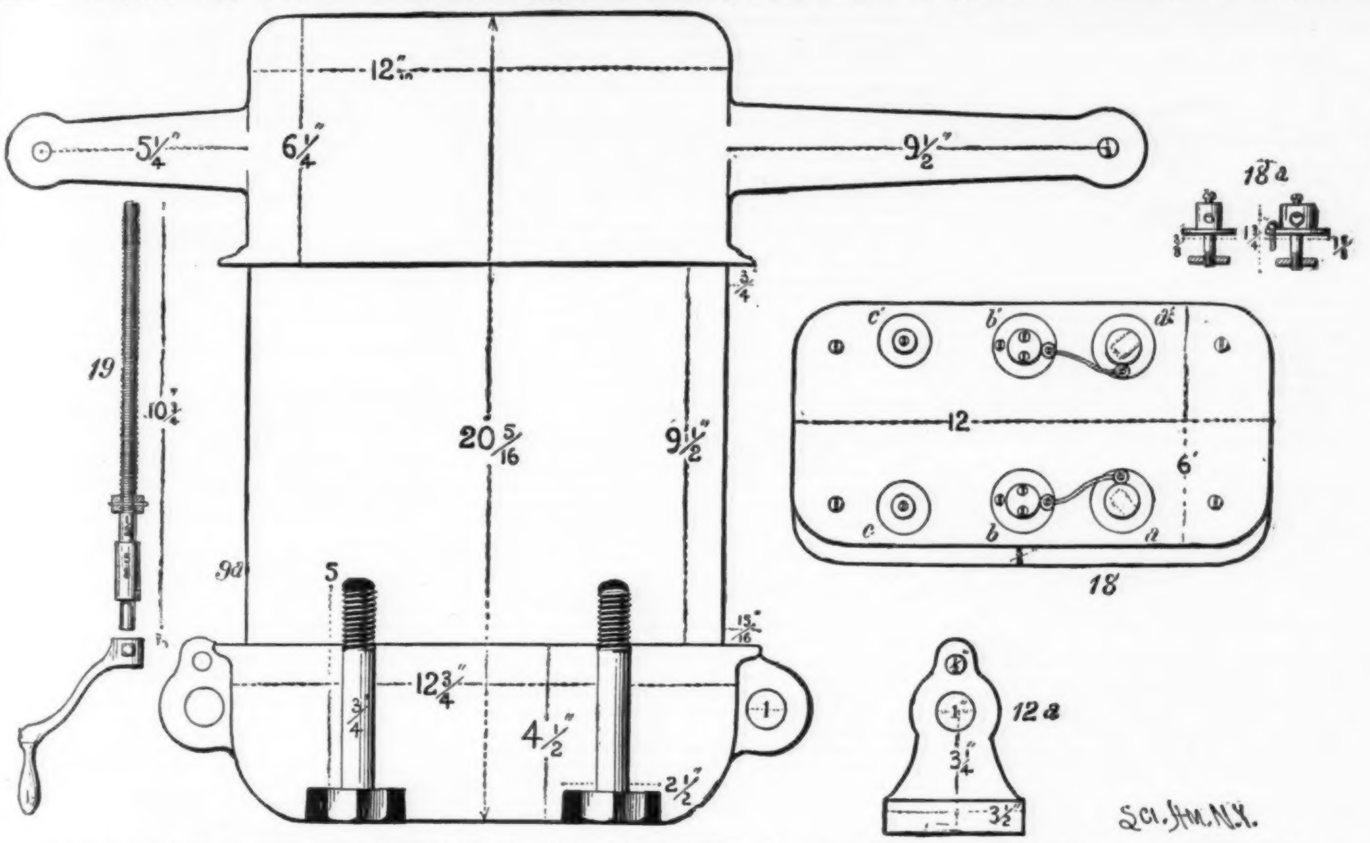
A ring of vulcanized fiber slipped over the commutator bars is provided in its outer edge with a groove in which is tied one end of the conical sleeve of canvas forming the covering of the armature, the sleeve at this time lying outwardly. The sleeve is then reversed and the free end is stretched over the terminals of the coils, and is secured to the armature by a binding of wire surrounding the canvas and clamping it tightly to the face of the armature. Six of these bands of wire are provided for confining the winding and preventing the armature from being destroyed by centrifugal force. The field magnet is furnished with ears at its ends, which are bored to receive rods inserted in castings designed for supporting the machine. In one of these castings is journaled one end of a screw, the other end of which enters a nut formed on the field magnet, the object being to provide means for shifting the dynamo or motor on its support to give proper tension to the belt running on its pulley.



PARTS OF THE SCIENTIFIC AMERICAN DYNAMO AND MOTOR. (Approximately one-fourth actual size, linear measurement.)

6, perspective view of journal box; 7, vertical longitudinal section of journal box; 8, horizontal section of journal box; 9, side elevation of the yoke and one arm of the field magnet; 10, horizontal section of the waist of field magnet; 11, diametrical section of pulley; 12, side elevation, partly in section, of the supporting frame; 13, details of brush holder; 14, longitudinal section of commutator cylinder; 15, one of the end plates of the armature core; 16, longitudinal section of armature core; 17, brush-holding yoke. (The dimensions marked on the drawings should be followed in preference to the drawings themselves.)

A slate slab secured to the top of the field magnet serves as a cover for closing the gap between the polar extremities of the field magnet. To this slab are secured six binding posts, *a*, *a'*, *b*, *b'*, *c*, *c'*; the binding posts, *a*, *a'*, are connected with the brushes by means of flexible cords, the binding posts, *b*, *b'*, are connected with the posts, *a*, *a'*, by fusible wires, the binding posts, *c*, *c'*, are connected with the terminals of the field magnet. When the machine is used as a motor, the connections are arranged as shown in Fig. 4. The leads, *d*, *d'*, through which the current is supplied, are connected with the wires, *e*, *e'*, through the double switch,



PARTS OF THE SCIENTIFIC AMERICAN DYNAMO AND MOTOR. (Approximately one-fourth actual size, linear measurement.)

9*a*, front elevation of field magnet without winding; 12*a*, end view of dynamo support; 18, slate slab; 18*a*, binding posts; 19, adjustable screw. (The dimensions marked on the drawings should be followed in preference to the drawings themselves.)

A; they are also connected with the wires, *f*, *f'*. The wire, *e*, connects with one terminal of a rheostat, B, having a total resistance of 10 or 12 ohms. The other terminal of the rheostat is connected with the binding post, *b'*. The wire, *e'*, is connected with the binding post, *b'*; the wire, *f*, is connected with the binding post, *c'*; and the wire, *f'*, is connected with the binding post, *c*.

Two commutator brushes are placed on either side of the commutator cylinder. The brush holders are pivotally mounted on rods, *g*, the said rods being electrically insulated from the yoke. The rods, *g*, project from the yoke, *h* (see Fig. 17), which is mounted on the inner end of the journal box at the commutator end of the machine. The brushes consist of rods of carbon held in the pivoted sockets, *i*, and the brushes are held in contact with the commutator cylinder by springs, *j*, connected at one end to the brush holder and at the opposite end to the tension lever, *k*, which is mounted adjustably on the rod, *g*.

The rheostat used in starting the motor, and also in regulating the current in the field magnet when the machine is used as a dynamo, is shown in Figs. 20 and 21. The upper and lower and front plates are formed of slate. These are supported in an iron casing which is provided with ears, so that it may be fastened against the wall. The series of coils in the box are connected so that the current entering at the binding post, *l*, passes up to the lower end of the coil 1, thence upward to the top of coil 2, thence downward to the bottom of coil 3, thence upward to the top of coil 4, thence through coil 5 and through the entire series to the end of coil 28, which is connected to the contact point, *n*, and the switch arm being on the said contact point, the current passes through the arm to the binding post, *u*.

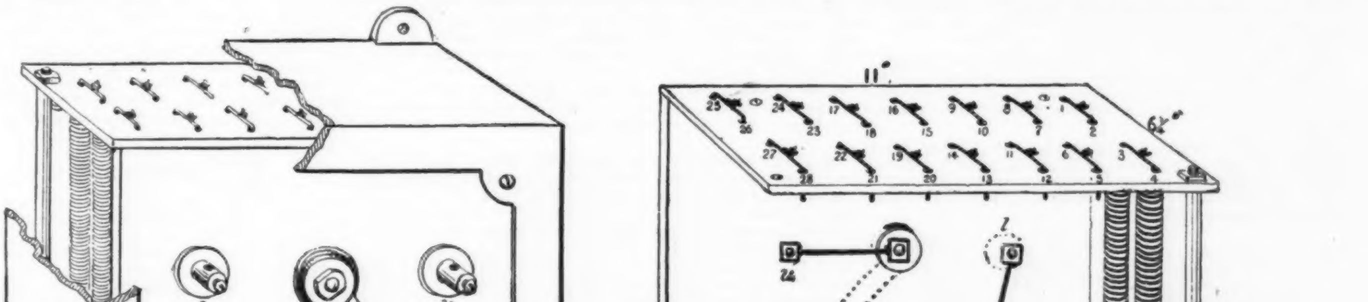
The contact point, *m*, is insulated from everything, so that when the switch arm is upon that point, the current is off from the rheostat and motor. By moving the switch arm forward to the contact point, *o*, the coils 25, 26, 27 and 28 are cut out and the current goes through the remaining coils. When the arm is moved forward to the contact point, *p*, the series of coils connected with the contact point, *o*, are cut out, and so on throughout the entire series. The moving of the switch arm gradually reduces the resistance. When the arm is on the contact point, *s*, the current flows through the last two series of coils, and when it is upon the contact wire, *t*, all the coils of the box are cut out of the circuit and the current goes directly through the switch arm and conductor connected with the point, *t*, to the binding post, *l*. The iron wire used in the construction of the resistance coils is No. 16, and the total resistance of the box is about 14 or 15 ohms.

To start the motor, the switch arm of the rheostat, B, is placed on the point, which introduces its full resistance into the circuit of the armature. When the switch, A, is closed, the current remains constant in the field magnet independent of the current flowing through the armature.

Another portion of the current flows through the wires, *e*, *e'*, the rheostat, B, the fusible wires and the binding posts, *a*, *a'*, to the armature, so that in starting the motor a minimum of current passes through the armature. As soon as the armature acquires considerable velocity, the switch arm of the rheostat is moved gradually forward, the rheostat being finally cut out, so that the full current flows through the armature. The speed of the motor is then automatically regulated by counter-electromotive force.

When the machine is to be used as a dynamo, the connections are made as shown in Fig. 5, that is to say, the leads, *d*, *d'*, are connected with the binding posts, *b*, *b'*. Here the current divides. The rheostat, B, in this case is inserted in the circuit of the field magnet. The current generated in the armature passes through the binding posts, *a*, *a'*, the fusible wires, and the binding posts, *b*, *b'*, where it divides, a portion going out through the leads, *d*, *d'*, another portion passing through the field magnet, in which is inserted the rheostat, B. The current is controlled by introducing more or less resistance into the field magnet circuit by means of the rheostat.

When this machine is designed for use with an E. M.



THE RHEOSTAT. (One-fourth actual size, linear measurement.)

F. of 220 volts, the resistance of the field magnet should be increased. In this case 40 pounds of No. 21 wire should be used instead of the F. M. winding given above, the armature winding remaining the same. As a 220 volt motor, the machine develops 6 horse power.

MECHANICAL FLIGHT.

By E. OAKES.

FROM time to time various plans have been proposed for building vessels or machines for navigating the air. In most of these schemes the balloon idea is assigned a prominent place, and if means are provided for giving it sufficient speed and for guiding the craft effectively,

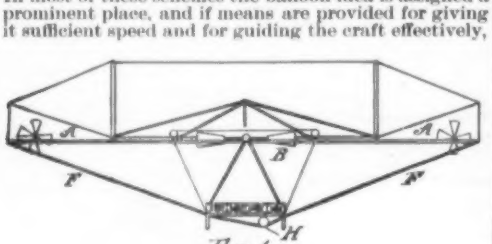


Fig. 1.

we shall have made some progress toward the accomplishment of the task; and if our machine carry the operator and possibly a companion, we shall at least have provided a practice machine upon which the engineers of the future air-line passenger and freight floats may learn the art of aerial navigation.

The plan of pushing a balloon through the air by means of screw fan wheels has been repeatedly tried, and has as often failed to give the craft a desirable speed.

The reason is obvious. The forward travel of the craft continually carries the wheel away.

From the point of resistance upon which it reacts, every increase of speed of the craft reduces the bite of the wheel upon the air. The same thing occurs in the case of boats propelled by a screw, but there is this difference in the water, the percentage of slip is comparatively small, and after the loss incident to the forward travel of the boat is deducted, a sufficient margin of effectiveness remains; but in the case of the air ship the margin left is not sufficient to propel the craft at a desirable speed; consequently there is a necessity for resorting to other expedients to secure such speed.

Nevertheless, within certain limits propeller wheels are useful, and I include them in my scheme. They will be useful at starting and much more effective when used to check speed or as a brake to stop the progress of the machine when occasion requires.

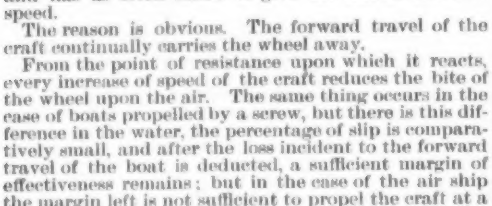


Fig. 2.

But when the wheel is turned to a horizontal position and acts as a lifting wheel, the forward motion of the craft greatly increases its effectiveness, as I have found by repeated experiments with models.

If, during the time in which the wheel makes one revolution, it is also carried forward one diameter, the force of the wheel is doubled. From this we may assume that, at all other comparative speeds, its effectiveness is increased in that proportion which its speed of rotation may bear to simultaneous horizontal movement.

The same argument applies to machines or models lifted or supported by wings which flap up and down.

The lifting effect of such flapping is in proportion to coincident forward travel of the machine. Thus, if, during the accomplishment of one down stroke, the wing is also moved forward one diameter, the effect is doubled, and if moved two diameters, the effect is multiplied three times, and so on indefinitely.

Here lies the secret of the birds, for with a change of wording, the same argument applies to the aeroplane also; and it is this that enables all sailing or soaring birds to glide through the air and be sustained on motionless wings.

The same reasoning applies to the wheels when turned on edge and used as guiding wheels. Every increase of speed of the craft adds to their efficiency.

In this machine I combine the balloon, aeroplane and screw fan wheel.

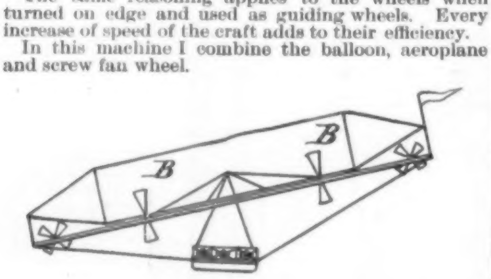


Fig. 3.

The intention is that the machine shall travel in precisely the same manner as soaring birds do, viz., by working up to a height and sailing down.

For their purpose altitude and momentum are one and the same, as either may be converted into the other. If a bird (soaring bird) has momentum he may sail upward on an inclined plane until it is expended, thus gaining altitude. If he has altitude, he may sail downward and acquire momentum, but by a succession of these plunges and more gradual ascents he must finally reach the ground. Consequently, there is a necessity for occasional flapping to maintain position. The resistance of the air and friction are constant factors tending to stop his progress; if these were removed, it might be possible that a bird or machine, once started at a convenient altitude, could sail on indefinitely.

The balloon is not intended to be of such power as to lift the entire weight of the machine, but only such portion as may be necessary to enable the machine to rise when the lifting power of the wheels is added thereunto.

The weight of the machine is the real power that drives it, and that portion of the weight of the machine in excess of the lifting power of the balloon is all that we can count upon to give momentum to the craft; but the effect of the wheels can be nearly doubled, because they can be made to pull down on a descending run. If we suppose their lifting effect to be one hundred pounds and down pull one hundred, we have a pressure of two hundred pounds to propel the machine on a descending run.

The lay of the machine upon the air is controlled by gravity. Cords, F, F, attached to the extreme ends of the aeroplane, pass underneath the car and are wound round the drum, H, a sufficient number of times to prevent slipping. The rotation of the drum takes on rope at one side and pays it off at the other, causing the car to travel toward one end of the aeroplane and recede from the other, thus changing the center of gravity and controlling the horizontal position of the aeroplane and balloon attached.

The aeroplane consists of a framework of wood, braced in such manner as to insure stability, and made as light as consistent with requisite strength. It is covered on the underside by thin plates of aluminum or other light material, and the balloon is rigidly attached to it. It is desirable that the balloon should present a smooth outline to prevent friction, and for the same reason it should have rigidity of form. I propose to make it of thin plates of aluminum, in form of a cylinder, with pointed ends.

The tendency of the contained gas is toward the highest part. To prevent any disturbance in the position of the craft from this cause, I make the balloon into at least three sections, or divide it by transverse partitions into three or more compartments.

As it is impossible to fill a non-collapsible metallic cylinder with gas in the same manner as balloons are filled, I propose putting bags, made of the same material as ordinary balloons, inside the metal envelope. In shape they will correspond to the shape of the metallic shell. These bags need not be filled to distention, but room can be left for expansion.

The metal cylinder need not be perfectly gas tight, but openings may be left on the underside through which air can flow in or out, as the contained bag expands or contracts.

The resistance of the air to the progress of the balloon is the factor that limits speed; consequently, it is desirable to reduce its size as much as possible. But even if the balloon did not carry any portion of the weight of the machine, it would still be useful, and act in the same way as an outrigger attached to a narrow canoe, to hold the machine in position. It gives equipoise and steadiness of motion; without it we have but one constant force—gravity—available to control the lay of the aeroplane, and the machine is captious and difficult to manage.

I propose to guide the machine by means of adjustable screw fan wheels, placed near the extreme ends of the aeroplane.

These wheels have movable blades, arranged in such manner as to admit of being changed to any desired position; while the wheel is in rapid motion, their working force may directed right or left, increased, diminished, or suspended without stopping them, simply by a movement of the governing lever. It is intended that these wheels shall run continuously and be ever ready to meet any emergency or turn the craft as may be desired when running idle, that is, revolving swiftly, but not acting upon the air in any direction.

Very little power suffices to keep them in motion; in fact, just as much as any idle pulley or wheel of the same weight.

This wheel makes an end to the problem of guiding an aerial machine. It enables them to be steered with ease and certainty.

The lifting wheels are of the same construction as the guiding wheels. If the fans are held in line with the plane of revolution, they exert no force, but the wheel runs idle when needed. A movement of the hand lever turns the blades and instantly throws the power of the wheel as desired. The frame of the wheel is also hung on journals. This arrangement enables it to be used either as a lifting wheel to work up or down, or as a propeller, to work forward or backward.

An automatic device, connecting with the engine, regulates the power and turns it on or off as may be needed, as the wheels, running continuously at the same speed, must use more or less power in proportion to the amount of resistance they may encounter in the varying positions of the blades.

It must be evident that these wheels admit of a great number of minor changes in construction. I have wrought them into many forms, some of which are universal, and their blast may be directed toward any point of the sphere, but the changes here shown are sufficient for the purpose. The forms shown in the cuts were drawn with a view to making the scheme intelligible without explanation. They give the same effective force as non-adjustable wheels, neither more nor less.

In order to balance the machine it is necessary to use at least two lifting wheels, one upon each side, but more may be added if desired, and the steering wheels can also be turned into lifting wheels at pleasure.

One large lifting wheel placed underneath the car will not do; it gives the craft a rotary motion.

The entire machine is a double ender. It will move in either direction equally well, and it makes no difference whether the wheels run from left to right or the reverse.

Although the machine is essentially a sailing or soaring device, it has, at the same time, all the advantages that propelling wheels are capable of giving.

The speed of a flying machine is that speed which it can make in a still atmosphere.

Even on calm days there is usually more or less wind. But when the machine is free in the air the steady flow of the sea of air surrounding it can neither help nor hinder, except as it may affect the time of passage from place to place.

But chop winds, swirls and counter currents are a continual menace and source of danger. To successfully combat them will require the constant vigilance of the pilot of the craft, and the machine must be provided with a steering mechanism capable of acting energetically and instantaneously.

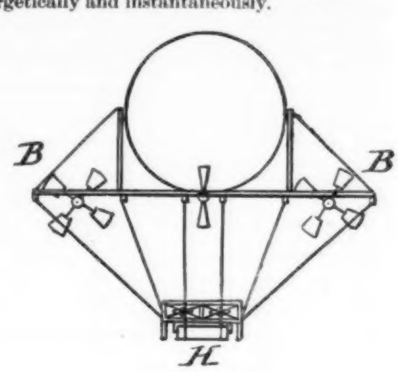


Fig. 4.

That the skill of the engineer may not be unduly taxed, the machine should consist of the fewest number of parts capable of doing the work.

Fig. 1 shows a side view of the machine. A A are the guiding wheels. The wheels, B B, one on each side of the machine, act as lifting or depressing wheels, or as propellers.

Fig. 2 shows the machine running on an ascending plane, and

Fig. 3 the same on a descending plane.

Fig. 4 is an end section.

Fig. 5 shows one of the wheels. The blades are pivoted on the spoke, D, and are held in position or moved by the spangle and cam, E.

Fig. 6 shows the method of attaching the wheel to the aeroplane. A quarter turn on the trunnions, G, changes the wheel from a lifting to a propelling position.

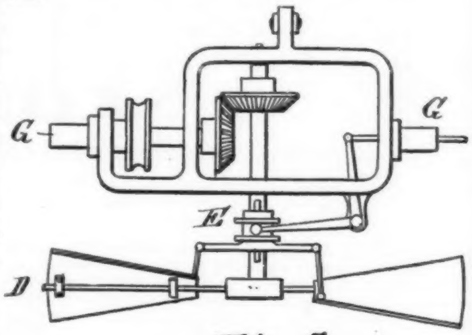


Fig. 5.

It is evident that the lifting power of the wheels is the measure of the force which drives the machine, and the greater the lift of the wheels, and the smaller the balloon, the greater the speed.

Just what speed will be possible depends on so many uncertain conditions that it would be difficult to figure it accurately, but the results of my experiments with models indicate that a speed of twenty miles per hour lies well within the range of possibility.

A machine upon this plan properly proportioned and trim built requires but very little power to enable it to run; in fact, it would be perfectly possible to make a trip of from one to two miles without any power whatever, but merely from the impetus of a good send-off or start, which could be got from a height, a bluff, or some such natural point of advantage.

To rise from the level ground is difficult for the larger sailing or soaring birds. The buzzard, for instance, must do some vigorous flapping to get a start,

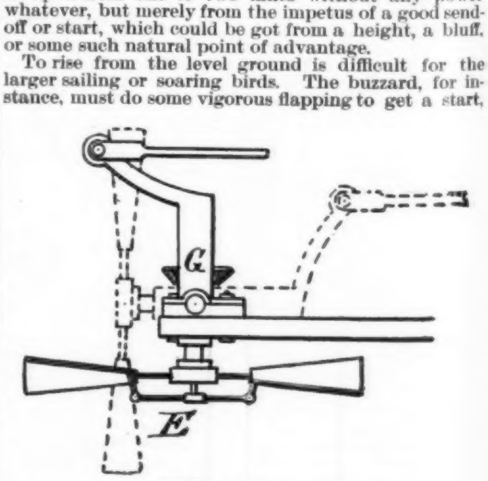


Fig. 6.

but having surmounted the difficulties of the first few feet of ascent, and acquired horizontal speed, his wings find support in the air, and slowing movements show that his task grows easier as speed increases, and when a sufficient altitude is reached, he extends his wings, and ceasing to labor, soars almost without effort.

The machine will encounter the same difficulties at

starting, and must surmount them by a proportionally vigorous effort. A light wind will render an ascent easier as it will increase the lifting power of the wheels. The machine being anchored head to the wind, the motion of the wind and the inertia of the machine make the mechanical equivalent of initial velocity.

The wind may be made to assist an ascent in another way. Cords attached to the aeroplane may extend forward to stakes driven in the ground. The front edge of the aeroplane being elevated, the wind will act against its under surface, and the machine be lifted as a kite is raised. The cords should attach in such manner as to disengage automatically when they have served their purpose, or as they approach a vertical position.

It is popularly supposed that there is need for something very extraordinary in the way of power, a necessity for some kind of engine vastly more powerful in proportion to weight than any now in existence, but really no such difficulty exists. There are a number of devices for developing power that are capable of doing good work.

The engine should be of the class which develops power only when needed. It should be capable of taking care of itself, requiring no attention from the engineer or pilot of the craft.

Gasoline engines are well adapted to the purpose, and special types could be built which would combine lightness and efficiency in a high degree.

The steel cylinders put up for the soda water trade, filled with gas at an enormous pressure, could be used to good purpose for short trips. Aluminum could take the place of steel.

Gas or ammonia engines of several kinds would be effective.

We need not consider economy. An hour's run will demonstrate the practicability of the scheme, and that once established, means will soon be found to reduce cost.

The machine as here shown is substantially the same as described in pat. No. 106,862, issued Aug. 30, 1870. I have introduced some minor features, changed the position of parts and simplified the mechanism, but the scheme remains the same.

It may be supposed that the ideas being so old are without value, but the birds were flying upon this plan then, and notwithstanding the march of improvement in other lines, they still continue to do so.

In conclusion, I will say that it is now nearly forty years since I commenced the task of building the flying machine. I have tried many experiments, and built scores of models, machines with valvular wings, and others with devices of various kinds of which I have made no mention, and in the light of experience gained, it appears to me that many of the things expected of and prophesied concerning the aerial ship are in the nature of things impossible.

But I do firmly believe and confidently assert that a machine of moderate size, capable of carrying one or two men, and of making a speed of twenty to thirty miles an hour in a still atmosphere, and of being guided and controlled with ease, celerity and precision, is a present possibility, and the flying machine will travel with a comparatively less expenditure of power than any other traveling device made by man.

513 Chandler Street, Danville, Ill.

AVIATION.

COMMANDANT RENARD, on the 23d of April last, delivered before the Society of Physics an interesting lecture upon aviation, that is to say, upon aerial navigation by means of apparatus heavier than the air.

"I am almost astonished," said he, in beginning, "at giving a lecture to-day upon the subject of aviation, I who pass for a systematic adversary of this science, because I am pursuing the solution of the problem of aerial navigation in an entirely opposite way."

Then he hastened to add that, far from wishing to proscribe aviation, he, on the contrary, believed in its future, although the science of aerostation was much maturer and better calculated to give immediate practical results.

After a succinct history of the tentatives that have been made by man from the remotest times to sustain himself in the air, the lecturer showed us the problem of aviation impassioning the public intermittingly, the fine experiments of Mr. Penaud, which in 1871 gave him an aftermath of actuality, the English and Americans submitting it to-day to potent means of study, and the learned Dr. Marey giving the laws of motion of the wings of the bird. He showed us also how much time and pains investigators have lost, for want of exact data, in inventing laws anew that have been known for a long time. Witness Prof. Langley, who believed that he discovered in 1888 the law that Commandant Renard calls the "law of the angle," and that Captain Faraud, in a communication to the Society of Civil Engineers in 1888, called the "law of small angles."

The lecturer afterward showed us aviation in the period of mathematical study with Navier. To this scientist, flight consisted in the vertical motion of two horizontal planes acting upon the air after the manner of two pistons; it is the orthogonal flight. This conception is false. It leads to the admission that a swallow, in flying, develops an impelling power equal to $\frac{1}{17}$ horse power per second; it is none the less the necessary starting point of the study of the resistance of the air.

In 1865 Messrs. Piobert and Morin found that a plane surface one meter square, descending at the velocity of one meter per second with an orthogonal motion, experiences from the air a resistance equal to 85 grammes. Commandant Renard, taking up these experiments, obtained a resistance of 84·75 grammes at a temperature of 0° and at a pressure of 760 millimeters.

The formula that gives the resistance of the air at a determinate velocity is

$$R = \varphi SV^2$$

R being the resistance, φ the constant coefficient, S the plane surface, and V the velocity. This formula is applicable for the velocities that must be anticipated in aviation, but not for very high or very low velocities.

The lecturer then stated the fundamental equation,

$$\frac{T^2}{P^3} = \frac{1}{\varphi S} \qquad [3]$$

where T is the power developed by the plane wings in the orthogonal motion and P the total weight of the bird. In order to obtain it, it suffices to remark that at the moment in which the bird is in equilibrium in the air, we have

$$P = \varphi SV^2 \qquad [1]$$

and

$$T = \varphi SV^3 \qquad [2]$$

On eliminating V, we fall upon equation [3].

Commandant Renard afterward reached the third phase of aviation, that of oblique flight. In 1763, Borda made some experiments upon the oblique motion of planes with respect to the air, whence may be deduced this important principle:

When the angle of a plane wing with the direction of its motion tends toward 0, the power that it expends in order to sustain a given weight in the air tends also toward 0.

All the consequences of this principle were not thought of at first. It is only in our day that Mr. Penaud has pointed out the small angle that the wings of the bird make with the real direction of their motion. He estimated this angle at 2° or 3°.

Many different formulas have been proposed for representing the resistance of the air to the motion of an oblique plane.

Let *ab* (Fig. 1) be the plane, V the velocity, $N\alpha$ the

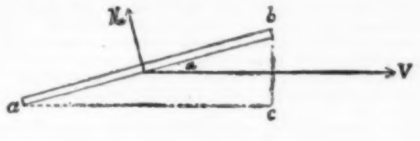


FIG. 1.

reaction of the air perpendicular to the plane. Newton and Navier after him admitted the formula

$$N\alpha = \varphi SV^2 sin^2\alpha$$

If this formula is true, there is no interest in attacking the air obliquely. In fact, let R be the horizontal component of the reaction of the air, and we shall have

$$R = P tg\alpha$$

If we admit that the angle must be small, we can write

$$R = P\alpha$$

whence

$$T = PV\alpha$$

and

$$\frac{T^3}{P^3} = \frac{1}{\varphi S}$$

The power necessary per unity of weight will, therefore, be the same as in orthogonal flight. The same is not the case when we adopt the formula proposed by Borda,

$$N\alpha = \varphi SV^2 nsin\alpha$$

We then obtain

$$\frac{T^3}{P^3} = \frac{sin\alpha}{\varphi S\, cos^2\alpha}$$

Whence we deduce for small angles

$$\frac{T^3}{P^3} = \frac{\alpha}{\varphi S} \qquad [4]$$

These equations lead to the principle that we have enunciated above, and which constitutes the law of the angle.

Which of the two scientists must we regard as right? Both and neither. The resistance of the air depends upon the form of the movable plane. If such form is that of a ribbon that cleaves the air by its long side, the fillets of air, pressed against each other, can only escape from beneath. It is in this case that the resistance approaches the formula of Borda. If the ribbon attacks the air by its small side, it approaches the formula of Newton.

Conclusion: It is necessary to adopt long and narrow wings, like those of the large fliers. In the swallow, the ratio of the length to the width is 5 to 6.

Professor Langley has proved this theory experimentally.

Commandant Renard then presented a series of experiments based upon the following principle (Fig. 2):

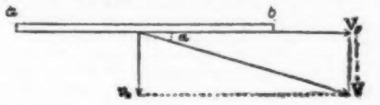


FIG. 2.

Leave the plane, *ab*, horizontal, and give it a horizontal velocity, *Vo*, which, combined with the velocity of descent, *vo*, produces a resultant, V, that makes with the plane the angle, α.

Light parachutes are detached simultaneously from an arm to which they are fixed. The simultaneousness is obtained electrically. One of them consists of four small vanes symmetrically placed as in a flier. Each vane is at right angles to the plane that passes through its axis and that of the flier. In a second parachute, each vane is oblique to this same plane, as in a propeller, so as to produce a rotation of the apparatus during its descent. It is found that the first reaches earth before the other. It is to be remarked that this retardation of the fall is obtained for the second apparatus without any expenditure of power.

Commandant Renard is led thus to define what he calls the quality of a wing or of a plane. From the equation

$$\frac{T^3}{P^3} = \frac{\alpha}{\varphi S} \qquad [4]$$

we deduce

$$P^3 \times \frac{\varphi S}{T^2} = \frac{1}{\alpha}$$

For

$$S = 1 \text{ and } T = 1$$

we have

$$\frac{P^3}{\varphi} = \frac{1}{\alpha}$$

That is to say, the weight lifted by a surface one meter square, developing a power of one kilogrammeter, is proportional to the cubic root of $\frac{1}{\alpha}$

It is this quantity that Commandant Renard calls "quality of wing." It will be seen that, for the oblique plane, it increases when the angle α diminishes, if we adopt Borda's formula.

These results have given the hope of greatly increasing the power of sustentation of a plane in the air by giving it a horizontal motion. From there, two ways of trying to solve the problem, viz., by the *helicopter* and the *aeroplane*. In the first, the motion is a rotation; in the second, it is a movement forward.

In studying the helicopter, we soon perceive that none of the formulas that we have given for the resistance of the air is applicable to it outside of quite narrow limits.

If, through mechanical means, we increase indefinitely the rotary velocity of one of the parachutes described above, it would seem at first sight as if, the angle α diminishing, the quality of the plane ought to increase without limit. Such is not the case, however. We reach the limit with some difficulty, and that, says Commandant Renard, when the power of sustentation of the revolving flier is that of a parachute having a surface equal to the surface engendered by the flier in its rotary motion.

The same is not the case with the aeroplane; but it is easy to see that other causes are capable of limiting the increase of its quality when the angle of attack diminishes. The friction ceases to be unimportant. At the epoch at which he was at the Regimental School of Engineering at Arras, Commandant Renard demonstrated that the resistance may be represented by the formula*

$$R = P\alpha + \frac{K}{\alpha}$$

He made some experiments of precision at the Chalais establishment of aerostation with a view of studying the quality of the blades of a propeller, and arrived at the conclusion that, through a suitable combination of the angle and of the velocity of rotation, the propeller works at a maximum like three-quarters of the plane that it engenders in revolving. This result evidently takes friction into account, the influence of which is feebler than for the aeroplane, the velocity being less.

The lecturer accepted, without dissension and with confidence, Prof. Langley's assertion that he possesses a machine weighing but 5 kilogrammes per horse power. Even under such conditions, a 5 h. p. machine lifting a supercharge of 75 kilogrammes would require two propellers, each eleven meters in diameter. We must not get too much scared, however, added he. If we carry the propeller, the air is constantly renewed. We are, therefore, benefited both by the rotary motion and the motion forward, and the limit of the quality of the propeller's blade increases.

We can thus reduce the power of sustentation of a weight of 75 kilogrammes to 1½ horse.

Commandant Renard does not believe that the helicopter is destined for an immense future. This apparatus would be useful especially for rising in the air at the moment of starting, and it would be necessary to rid one's self of it immediately in order to make use of the aeroplane, which does not rise of itself, only upon first taking on an initial velocity upon an appropriate surface.

To Mr. Penaud, and, in our day, to the Americans, the aeroplane is the ideal type of the apparatus of aviation. In the aeroplane, as in the balloon, it is necessary to study stability on the one hand and direction and velocity on the other. The conditions of stability are very simple: it is necessary, in the first place, that the force applied to the body shall pass through the center of gravity. Moreover, it is necessary to assure the orientation of the apparatus by a process analogous to that employed for arrows. At the posterior part there will be placed a light tail (Fig. 3). In order

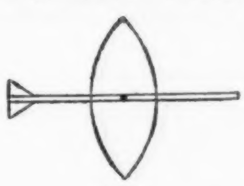


FIG. 3.

to oblige the plane to remain inclined with respect to the direction of the motion, it suffices to bend the tail of the arrow slightly upward. But, as we have before said, the angle, α, of the inclined plane with the direction of the motion has a limit beneath which the resistance due to friction is preponderant.

If the motion of a bird followed exactly the laws that have just been enunciated, the power expended in flight would still be considerable. A raven, for example, might produce the power necessary to raise itself 1·57 meters per second by the ordinary means of mechanics. Such a result can only excite surprise if we reflect that man has trouble to lift himself 0·2 meter per second, and is obliged to stop in a short time.

Some recent experiments, and especially those of Prof. Langley, have proved that the normal reaction of the air, for small angles, upon an aeroplane of suitable form may be represented by the formula:

$$N = \varphi SV^2 \times 5\alpha \qquad [5]$$

Let us take as a measure of the power produced by a

* To arrive at this formula, it must be remarked that it is applicable only to an aeroplane in rectilinear and uniform motion and attacking the air at a small angle. The general formula would be:

$$R = P\alpha + \varphi\sigma V^2$$

σ being a coefficient that depends both on the surface and form of the keel. But if the apparatus is in equilibrium, we have:

$$P = N\alpha = \varphi SV^2 n\alpha$$

whence

$$R = P\alpha + \frac{P\sigma}{Sn} \times \frac{1}{\alpha}$$

bird the height, H, to which the same power would permit it to raise itself on taking a purchase on solid bodies. We find that, under the conditions represented by the above formula, the power produced by the raven would be reduced to 0·75.

Finally, several aviators, Mr. Goupil among others, have studied the influence of curved surfaces upon the resistance of the air. They have succeeded in greatly increasing the power of sustentation, and the height, H, is thus reduced to 0·3 meter.

FIG. 4.

Here, then, we have reached a power very near that which man can produce, although he is one of the animals least organized for the expenditure of power.

The lecturer exhibited several specimens of mechanical wings. That of Mr. Pline consists of a curved frame, *b c* (Fig. 5), upon which is fixed a light sail, and which terminates in a sort of handle, *a b*. One grasps the latter, and if he tries to strike an object with the flat of the wing, he feels the latter turn in his hand. This experiment shows that the bird could not strike the air orthogonally without exerting great stresses. The wing acts after the manner of an alternating propeller.

FIG. 5.

Mr. Penaud, in 1871, and, after him, several other aviators, Mr. Jobert among them, have succeeded in constructing mechanical birds whose flight is very satisfactory.

The lecturer finally exhibited a small model of an aeroplane provided with a propeller (Fig. 6), which he caused to make a trip across the hall.

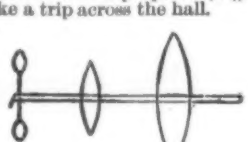


FIG. 6.

In conclusion, the lecturer proclaimed that he was no longer any more of a partisan of one system than of the other. The balloon will permit of carrying heavy loads in calm weather and the aeroplane of carrying light loads in all kinds of weather and very rapidly. But the destinies of the balloon appear to be nearer at hand than those of the aeroplane, and, consequently, it is toward the first that he is directing his efforts.—*Le Genie Civil.*

COMPRESSED AIR FOR POWER.

CONSIDERABLE attention has lately been given to the development of what may be properly termed the compressed air system, and already it has become a subject which has interested mechanical engineers to the extent that it is being experimented with, as a means of furnishing power for mechanical purposes by a system of underground conduits or conducting pipes.

The utilization of compressed air for power purposes, either locally or at a distance, is not a new discovery, but has been known and utilized more or less extensively and successfully for nearly 200 years.

Dr. Peppin, of Blais, France, to whom we are indebted for quite a number of other valuable inventions in connection with the production and transmission of power, was, so far as can be ascertained, the first to make use of compressed air as a means of transmitting power, in the year 1700. His experiments, which consisted of compressing the air by means of a fall of water, and leading it by pipes a distance of about a mile, where it was turned into the cylinder of a pump to operate the piston, did not prove satisfactory or practical, although his theory was good.

About the year 1800 a Welsh engineer experimented in a similar way, and endeavored to utilize the compressed air in driving a blower for a blast furnace, but met with little success. About fifty years ago a patent was taken out in England for the application of compressed air to hoisting machinery, the air being compressed by an air pump located at a central station and conveyed by pipes to the different works where it was to be used.

In this connection the following description of an aëro-hydro-dynamic wheel, invented by Mr. Calles, of Belgium, as given in the Journal of the Society of German Engineers, may be of interest:

"It consists mainly of a wheel adapted with buckets similar to those in an ordinary water wheel, and completely immersed in a tank filled with water. This wheel carries a toothed inner rim, which works a pinion adapted to the transmission shaft.

"Most transient visitors to the Paris Exposition, as they walked past this contrivance, hardly gave it a look, believing that it was the pinion that gave motion to the wheel, and considered it as some sort of stirring or washing machine; but the inverse was in reality the case, as it was the immersed wheel which gave motion to the pinion by the direct action of slightly compressed air.

"The general disposition of the parts will be readily understood by reference to the diagram:

"The diameter of the wheel exhibited was 9 feet, its breadth 4½. It carried 30 buckets, curved in such a manner that 13 of them (figured to the left) always retained a certain quantity of air in their upper portion.

"The air was introduced under the bottom of the wheel, through a curved pipe. The air thus blown into the buckets had naturally a tendency to gain the surface of the water with a force equivalent to the weight of displaced water, and this upward tendency caused the rotation of the wheel, and at the same time brought back the discharged buckets successively before the orifice of the tuyere.

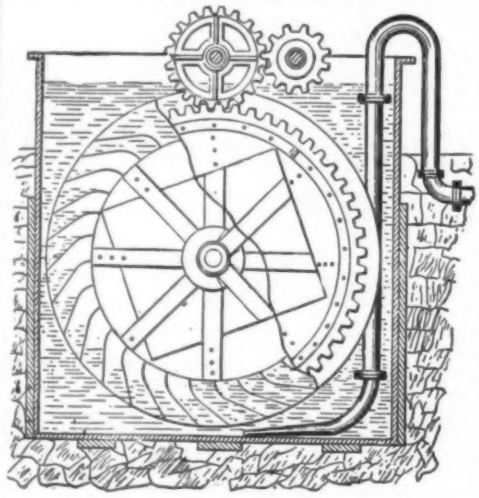
"The wheel made six revolutions per minute, so that three buckets were filled with air every second.

"The air rushed with a velocity of 32 meters per second through a pipe 0·095 meter in diameter. The quantity discharged was consequently 0·227 cubic meter per second, equivalent to 0·075 cubic meter for each bucket or cell. During every second of time 13 buckets were thus partly filled with air, their total capacity being 0·983 cubic meter. The same bulk of water being displaced, a constant power of approximately 983 kilogrammes or 2,163 pounds per second was obtained.

"The internal diameter of the wheel being 2·26 meters, its annular surface 3·05, and its width 1·5, it is readily computed that the 30 buckets occupied a space of 4·585 cubic meters, and that each cell cubed 0·153 cubic meter, a portion of which space, equivalent to one-half, or to 0 075, alone contained air.

"If the application of force be supposed to have been applied at one-quarter of the depth of the wheel under water as an average, then the speed of any point of its surface would have been $2·445 \times 6 \times w \div 60 = 0·77$ meter = 30 inches.

"Multiplying this speed by the 983 kilogrammeters, we find the power transmitted per second to have amounted to 757 kilogrammeters. If we deduct herefrom 20 per cent. for losses by friction, reaction of water, etc., there remain 606 kilogrammeters, or 260,000 foot pounds, as available working power per minute—equivalent to an eight horse power.



COMPRESSED AIR WHEEL.

"The forcing of the air was effected by means of a 9½ horse steam engine—the compression of the air being one-quarter of an atmosphere. In the example exhibited, 83 per cent. of the power of the engine was thus transmitted to the wheel, and this through a pipe 510 feet long and presenting 14 elbows.

"The above-described new method of transmission of motion may prove of very great value in many situations where the application of belts and shafting, parallel motions, such as are used in mines, and other similar contrivances, is impracticable. It might also be applied with success to the driving of machinery in cities for the smaller branches of industry—the compressed air in such a case being conveyed through mains and pipes laid below the surface of the streets in the same manner as is at present practiced for our water and gas supplies."—*Manufacturers' Gazette.*

TABLET OR COMPRESSED TEA.

BRICK tea has usually but little to commend it, as it is known to be composed of the sweepings and dust of the Chinese tea factories. Its chief market is Russia, which took from China last year 2,005,548 lb., one-half of the usual export, due, it is said, to the scarcity of tea dust. A new article in tea has, however, recently sprung up in China, in the form of tablet tea, which appeared in the trade returns of Kiukiang for the first time last year, machinery having been erected there for its manufacture, and the quantity shipped from that port was 493,392 lb. Tablet tea is made from the very best quality of tea dust. It is formed, by pressure alone, into small cakes, which are perfectly hard and solid, and somewhat resemble chocolate in appearance. The material is not, like brick tea, moistened with steam before being compressed, and the flavor is not in any way impaired by the process of manufacture. As it takes up little space and is most unlikely to get spoilt or damaged, it is recommended as a convenient form of tea for travelers, backwoodsmen or armies in the field. With these conveniences and a guaranteed good quality, there is no reason why tablet or compressed tea should not become generally used.

THE WOOL INDUSTRY OF THE PUNJAB.

THE United States consul-general at Calcutta, in a recent report to his government, states that the Punjab, with its 6,551,180 sheep and its 83,000 maunds of wool, annually made into shawls, carpets, blankets, etc., holds an important place in the sheep and wool industry. Shearing in the Punjab is done twice a year generally, though in a few of the districts there is an intermediate shearing in June. The wages paid consist of one-twentieth of the wool shorn. A man can shear twenty unwashed and twenty-five washed sheep in a day. Wool sorting in the Punjab is done in a very primitive style, and in some parts it is not done at all. Washing of the wool is not common, nor is it very necessary, except in the case of wool loaded with sticky matter. Unless done carefully and with suitable soap, it is very bad for the wool, and picking by hand or some other process is, in every case, still necessary for the removal of burrs, thorns, seeds, etc., which are entangled in the fibers. The picking out by hand of foreign bodies is done everywhere. It is a very tedious process in the case of wool grown in places abounding in thorny bushes and undergrowth, and the workers are nearly always women. The mere process of hand-picking involves a certain amount of teasing out of matted portions of wool; but where scutching and combing are uncommon—a state of affairs which appears to exist in the Jung district and in Jullinder and Ludhiana—something more than this is necessary. The wool must be reduced by hand to a mass of fluff; but to effect this, in most districts either the *pinjan* (bowstring) or the comb is used. A bow is suspended, string downward, at such a height that the string passes through the wool to be operated upon. The string is then made to vibrate violently, either by twitching it or by striking it with a hammer, and the vibrating string catches up and scatters the wool about. The instrument is used in nearly every district of the Punjab, and nearly everywhere the work is done by men of some low caste. In most places there is a separate caste of *pinjas*. The bowstring and the comb are not merely alternate instruments for effecting the same purpose: the former opens out the wool and loosens its mass, but leaves the fibers lying confusedly in all directions; the latter tends to open the wool, and also to lay the fibers side by side in parallel lines. The former is used when woolen thread is wanted, the latter when the spinning of worsted is the object. The combs used in the Punjab are of two sorts, single and double. The double are reported to be used only in Gujurn-walla, Amritsir and Lahore, and the single comb is found in Sialkot and the Ferozepoor. The double comb (*shana kanga*), which is the more effective of the two, consists of a piece of wood laid on the ground, with two parallel rows of vertical iron teeth standing on it, there being twenty teeth about four inches high, and the intervals between the two rows and between the teeth being one inch and one-half an inch respectively. The teeth are rigidly fixed to the platform, which is kept steady by the operator's feet. He does the combing by taking a flock of wool, striking it upon the teeth, and drawing it gently downward through the teeth at right angles to the rows.

The single comb is a very primitive instrument, and has very imperfect effects. In its rudest form it is a mere *panja*, or claw, which cleans rather than combs. Neither the single nor the double instrument is used for combing short-stapled wool, nor could it be employed with any effect for such a purpose. The wool, when teased, or scratched, or combed, as the case may be, is made up into balls (*punis*). The next operation is spinning. The *charkhi* is formed of two parallel disks, the circumferences of which are connected by threads, and over the drum so formed passes a driving band, also made of thread, which communicates a rapid motion to the axis of the spindle. The end of a *puni* is presented to the point of the spindle, which seizes the fiber and spins a thread, the *puni* being drawn away as the thread forms, as far as the spinner's arm will reach. The thread is then slackened and allowed to coil itself on the body of the spindle until the latter is full, when it is removed. In some parts, notably in Cooloo, the *charkhi* is quite unknown, and the instrument used is the *dherna* or *takli*, a pointed instrument, similar to the unattached spindle of an old-fashioned spinning wheel, with a disk at the blunt end. A portion of a *puni* is drawn out and held to the upper part of the instrument and wound round it. The *dherna* is then spun round in the hand, and when it has got firm hold of the wool it is allowed to hang in the air suspended by the thread it is spinning, the right hand of the operator keeping up the rotary motion, while the left hand regulates the draught of the wool. When the thread is getting so long as to put the *dherna* out of reach or to let it touch the ground, the draught of wool from the *puni* is stopped and the piece that has been spun is wound on the *dherna*.

The *charkhi* is said to produce a more even and reliable thread than the *dherna*, owing to the greater regularity of the rotary motion in the former machine.

In the hills spinning is done by all classes of both sexes and all ages, from ten years and upward. Consul Merrill says that, in Cooloo, every tenth person met on the road is spinning wool with a *takli*, as he or she walks along, and it is no doubt the portability of the instrument, as much as anything else, that causes it to be used instead of the *charkhi*.

When yarn has been spun, it is generally found that it is too thin, in places, to bear the strain of weaving, or when a coarse, thick fabric is required. The yarn has, therefore, to be doubled or trebled, and sometimes more than three folds are given. For twisting, as this process is called, the *charkhi* can be used, and also a form (called *masan*) of the *dherna* or *takli*, the difference being that the upper end of the spindle has a narrow, curved groove, about half an inch long, running from the point along and round the rod, and in this groove the threads, twisted together, are run.

Yarn, single or double, is sold in the hills, in balls or on reels of various shapes; but, before weaving, it must be wound on reels, and the warp prepared. Two reels are fixed at the ends of sticks on a pivot on which they can revolve. A double row of sticks or reels is then planted on the ground at intervals of about two yards, extending either in a straight line or in a loop to the length which the piece of cloth is to have. The

warp layer then takes a stick and reels in each hand and walks along the line, dropping the threads, one inside and the other outside the sticks alternately, so that the two cross each other between each pair. Having got to the end of the line, the operator returns in the same way, and so on, up and down, until enough threads have been laid to make the required width of the fabric. If the cloth is to have a longitudinal stripe or a check, reels of different colors are used, and the proper number of threads laid on with each color. Some of the wool used in the Punjab is brought from Beloochistan, where the pasturage is peculiar, and from Cashmere, where the water is said to contain valuable qualities.

Thousands of the inhabitants of Cashmere in the last fifty years have come over from their native valley to settle in the Punjab, and, encouraged and assisted by European agents, have engaged in the manufacture of shawls.

MUD: A MATERIAL IN PERSIAN AND EASTERN ARCHITECTURE.*

By WILLIAM SIMPSON, R.I., M.R.A.S., Hon. Assoc. R.I.B.A.

IT is necessary to premise that under the term "mud" I include sun-dried bricks. When bricks have been burnt in the fire, the material becomes entirely changed, and ceases to be mud, so I exclude them from consideration in the present paper as a building material. Wet earth made into blocks and dried in the sun differs in no way from a layer of the same laid on a wall.† Both methods were used in the East, and often combined in the same building. The reason for this is soon found out if you attempt to raise a mud wall. A layer of two or three feet thick must be allowed to dry and consolidate before another is placed on it, because the weight above would press out the soft material below, and the whole would tumble down. In some localities a layer of mud is put down at the commencement, and while that is drying, bricks are made to be placed above.

It was during the cold season of 1884-85, in traveling through Persia at the time of the Afghan Boundary Commission, that the importance of mud in connection with building and architecture first attracted my attention. I had to pass from Tehran eastward, through Khorassan, and into Afghan Turkestan.‡ Along the whole of this route mud is the building material. Some of the serais, that is, caravan serais for the accommodation of travelers, are of burnt brick, but these are about the only exceptions. Not only villages, but large towns are built of mud or sun-dried brick. The defensive walls are of the same material; even such large towns as Sabzawar, Nishapur, Meshed, § and new

FIG. 1.—THE MESHED GATE, NEW SARRAKHS, ON THE HERI RUD.

Sarrakhs, are fortified with walls of this kind. Fire-burnt bricks may have been more frequently used in former times, that was when the country had been more prosperous, and before Turkoman raids began. On the remains of former towns a few fire-burnt bricks ‖ might be seen scattered about, but the great mounds seemed to be composed of nothing but earth, suggesting that these fragments were the exception. On realizing this almost exclusive use of one building material, in one region, my mind naturally recalled what I had seen in India; where, although stone and fire-burnt brick are largely used, yet the villages are over very large districts wholly constructed of mud In Afghanistan it is the same. The fort at Peshawer, which was Afghan territory up to Runjit Singh's time, is a mud one. Jellalabad is surrounded by a mud wall. From the Khyber Pass to Tehran the towns and their defenses, as well as the villages, are almost identical in their material as well as in their general appearance.

These statements show that over a large geographical space in the eastern world the building material, at the present day, is almost exclusively mud. I have been thus far speaking of what I have seen with my own eyes. To this may be added the practice of other countries. I believe that it is the same over most of Central Asia. It is now accepted that in Mesopotamia it was largely employed; and we know that in Egypt, from the earliest times to the present day, it has been the principal means employed in structural erections. It was largely used in Greece in ancient times, and also in Spain. It was known in South America and all along the Pacific Coast, from Peru to San Francisco. The word "dobies," for sun-dried bricks, is a familiar term—this is derived from the Spanish word *adobes*. ¶ In 1873, I visited the original church dedicated to St. Francis, and which gave its name to the now well-known town in California; this church was constructed with "dobies." Mud houses were not uncommon in England in the past; and they are yet known in Devonshire, where the stuff they are constructed with is called "cob." I might largely increase this list of localities, but enough has been given to show how extensively mud has been used in the past as well as in the present for building purposes. I am under the impression that its importance in connection with building has hitherto been overlooked. The lithic architecture of Greece having been traced back to wooden forms has led to the study of wood as an early structural material; and up to the present little or nothing has been done with mud.

Owing to this it has been generally assumed that wood supplied the first means by which the primitive man had formed a shelter to himself as a protection from the weather. The Australian native, as he was represented some years ago at the Colonial Exhibition, was a good example of the simple beginnings of wooden architecture; but a very slight consideration will bring to the mind the possibility that the use of mud might, at least, be equally primitive. It would all depend upon where the primitive man found himself; if trees were scarce, or none whatever were to be found, the wetting of earth and raising a wall with it must have been very soon discovered. The children making "mud pies" might have given the first hint. Once begun, the progress of mud architecture would be considerable. Those who began their architectural style with branches of trees could not have made any advance until some kind of implement was invented by means of which the wood could be cut and fashioned; and the "stone age," when stone tools came into use, is a comparatively late one in man's history. The mud builder, on the contrary, required no tools; his hands were sufficient for every purpose. He may have been content at first with an inclosure formed by four walls. A covering of grass or reeds would soon suggest itself; this, although rude and primitive, would be the first complete human habitation. But more than that, it would be the beginning of the "house"—the "home," which, from the relations and associations it produced, must have been one of the most important steps in the history of early civilization. This, of course, is only a speculative suggestion as to what took place, but in the nature of the conditions it is a probable one. We find a confirmation of this when we remember that the Nile Valley and Mesopotamia, two pre-eminently mud building regions, are now noted for their very early civilization.

The great antiquity of the use of mud as a building material can be established from a number of references to history. Like most things that were important to man in his early condition, this can be traced back even to the mythical period. In Persia, at least, we have traces of it. Firdusi, in the *Shah Namah*, relates how Jemshid, now known as a mythical personage, introduced a better civilization among the people; among the improvements it is told how "He taught the unholy demon train to mingle water and clay, with which, formed into bricks, the walls were built, and then high turrets, towers, and balconies, and roofs, to keep out rain, and cold, and sunshine." It is naturally inferred that the bricks made by the children of Israel in Egypt were sun-dried from the use of the straw in them. The making of bricks is often represented in the sculptures of Egypt. M. Maspero thus describes the process: "The ordinary Egyptian brick is a mere oblong block of mud mixed with chopped straw and a little sand, and dried in the sun. At a spot where they are about to build, one man is told off to break up the ground; others carry the clods and pile them in a heap, while others again mix them with water, knead the clay with their feet, and reduce it to a homogeneous paste. This paste, when sufficiently worked, is pressed by the head workman in moulds made of hard wood, while an assistant carries away the bricks as fast as they are shaped, and lays them out in rows at a little distance apart to dry in the sun."* As to the speed with which these bricks could be made, M. Maspero has to judge from the workmen of the present time, and he says that a modern good workman can easily mould 1,000 in a day, and that after a week's practice he may be able to produce 1,200 or 1,500, and some can turn out as many as 1,800. As the modern appliances are the same as were used in former times, he assumes that the results would be similar. The dimensions generally adopted for ordinary bricks were 8·7 by 4·3 by 5·5—I presume these numbers represent inches; a larger size were 15·0 by 7·1 by 5·5.† He says, "Burnt bricks were not often used before the Roman period." In a note he adds that such bricks "are found of Ramesside age at Nebesheh and Defenneh; even there they are rare, and these are the only cases I have yet seen in Egypt earlier than about the third century A.D." This note is valuable from its showing how exclusively sun-dried bricks must have been the rule in ancient Egypt.

Mr. Flinders Petrie has, in his explorations, come upon, in more than one instance, what might be called the "foundation stone" of Egyptian buildings, but as there was no stone, but a number of articles, such as gold, silver, lapis lazuli, etc., a more exact term to give it would perhaps be that of "foundation deposit." Among the articles, and generally in a very central position, he always finds a small model of a mud brick.‡ This will show that along with the other objects it had most probably acquired some symbolic signification.

Maimonides gives a description of building mud walls; he says, "The builders take two boards, about six cubits long and two cubits high, and place them parallel to each other on their edges, as far apart as the thickness of the wall they wish to build; then they steady these boards with pieces of wood fastened with cords. The space between the boards is then filled up with earth, which is beaten down firmly with hammers or stampers; this is continued until the wall reaches the requisite height, and the boards are then withdrawn."* I understand that this is taken from the Talmudical authorities, but the great rabbi does not explain in what part of the world it was practiced.†

Sanchoniathon, or whoever it may have been that wrote under that name, mentions Chrysor, and identifies him with Vulcan, as having invented many useful things; and it is quoted that "Men worshiped him after his death as a god, and they called him Diamichius, *i. e.*, the Great Inventor; and some say his brothers invented the making of walls and bricks. After these things, of his race were born two young men, one of whom was called Technites—*i. e.*, the Artist; the other, Autochthon—*i. e.*, Earth-born, or generated from the earth itself. These men found out how to mix stubble with clay, and to dry the bricks so made in the sun."

According to Professor Sayce, the Assyrians had a month called Sivanu, which he translates the "month of making bricks." The Accadian name had the same signification; and it corresponded to the month of May. This would be the season after the rain, when the sun had begun to be hot, and the drying of the bricks would be easily accomplished.

These references will show, at least, how important this building material must have been looked upon in very early times. Its first use, or invention, was ascribed to mythical personages, thus attributing to it a kind of divine origin. In our own age it is difficult to realize how such ideas could have existed in the past, but from the authorities quoted there can scarcely, I think, be much doubt on the subject.

I shall now give a few details of the manner of building in mud, most of which are derived from what I saw in Persia. Many of the methods I saw there I have since found are also practiced in other parts of the world.

It was pointed out to me that, in the larger towns, on entering a house, you have often to descend from the level of the street to the ground floor. It was explained that this results from utilizing the earth on which the house stands, and thus saving the expense of transporting the building material from outside the town.

In good houses a foundation is laid, varying from two to four feet in depth, formed of rough stones or broken fire-burnt bricks, and piled up with mud and lime. This is carried up a foot or so above the ground, before the mud wall is commenced. In villages, where everything is rude, this foundation is made of any kind of rubbish that is found handy. This is a very interesting feature of mud architecture, to which I shall have something to say further on. Its object is no doubt to give strength where the wall would be liable to friction from the street traffic; and probably to prevent to a certain extent damp from rising. It would also be a safeguard against another serious danger—that is, if water were to accumulate by any chance round the base of the mud walls, and remain long enough to soak through, a very serious catastrophe might take place from the house tumbling down. I cannot recall to my memory any foundation of this kind in the mud houses of India. Village houses in the northwest of that country are usually built on a *chabootra*, which is a raised platform of mud, about a couple of feet in height, and this forms the floor of the house. This platform, by raising the foundation of the walls above the ground, may, perhaps, serve some of the purposes of the layer of stones in the Persian foundations.

The walls of Persian houses vary from two to four feet in thickness. This depends entirely on the quality of the house and the means of the builder. Thick walls make a cool house, and that is a desirable thing in the climate of Persia. If upper rooms are required, a greater strength of wall will be necessary. The mud is either laid on in layers or in the form of bricks.‡ As already explained, a layer of two or three feet of mud must be allowed to dry to a certain extent before another is laid on it, else the soft mud below will give way from the weight above. On this account both methods are generally practiced. I remember an officer who tried to make a mud hut for himself, when General Sir Samuel Browne's force was in Jellalabad. In this case, the walls were run up at once the full height required; this was not very high, for it was a small place, and he had dug a foot or two down below the surface for his floor, but his walls tumbled in. When he adopted the system of layers—letting each dry before the other was laid on—he succeeded, and made a very comfortable place for himself. In garden walls hollow bricks are used for the top, to give lightness. These bricks are called *sanduk*, a word meaning "box," which is descriptive of their character.§ The tendency in mud building to produce thickness below in the walls and lightness above is most marked in the walls of villages and towns. These are all built with a visible batter. The earth taken out to form the ditch gives an abundant supply of material for a town wall, and a thick solid mass at the base is necessary to give strength to the defense.

Where wood is plentiful, as in the province of Mazenderan, flat roofs are the rule. In large districts of Persia wood is scarce. I understand that south of Tehran there is very little timber, and there is also great danger from the white ants, so the vault or barrel roof is the usual means employed. According to Strabo, it was the same in Mesopotamia; he says, "all the houses are vaulted on account of the want of timber."‖ These vaulted roofs were frequent enough along the route I traveled. I have seen whole villages with them. Square buildings would have a dome, and a semi-dome at one end of a barrel roof seemed to be a favorite method in that part of Persia. What struck me with surprise was the facility with which these villagers

* A paper lately read before the Society of Arts, London. From the *Journal*.

† Bricks of this kind, "when placed one upon another after being imperfectly dried, combined, under the influence of the weather and their own weight, into one homogeneous mass, so that the separate courses become undistinguishable. This latter fact has been frequently noticed in Assyria, by those who had to cut through the thickness of walls in the process of excavation." Perrot and Chipiez, "A History of Art in Ancient Egypt," vol. i., p. 113.

‡ See paper on "Experiences on the Afghan Frontier," by William Simpson. *Journal of the Society of Arts*, March 26, 1886, where details of the journey will be found.

§ The blocks of Figures 1 to 5 and 7 have been kindly lent by the Council of the Royal Institute of British Architects, for use in the illustration of this paper.

‖ At Kala-i-Maur, on the Khushk, I measured some fire-burnt bricks, which were 11¾ inches square, and the thickest were 2¼ inches thick. Another was 10¾ inches square. There was an oblong brick, 7½ inches long. It looked much like our own bricks, but it was only 1½ inches thick. Perrot and Chipiez state that the ancient bricks in the Euphrates Valley were from 15½ to 15¾ inches square, and from 2 to 4 inches thick. Persian sun-dried bricks are about 8 inches square and 2 inches thick.

¶ *Adobes*, or *dobies*, is probably a variant of the Arabic *tob* or *toob*, allied again to the Coptic *tobi*, which was also the Egyptian word for brick.

* "Egyptian Archæology," p. 3.

† In a note at the end of the volume the author says that "in the Delta, at least, the sizes of bricks, from the Twenty-first Dynasty down to Arabic times, decrease regularly. Under the Twenty-first Dynasty, they are about 18 by 9 by 5 inches; early in the twenty-sixth, 16½ by 8¼ by 5; later, 15 by 7½; in early Ptolemaic times, 14 by 7; in Roman times, 12 by 6; in Byzantine times, 10 by 5; and Arab bricks are 8 by 4, and continue so to our times." Persian sun-dried bricks, at the present day, are generally about 8 by 2.

‡ See the *Illustrated London News* for September 11, 1886, where drawings of these objects, with their relative sizes and position, are given.

* *Transactions* of the Soc. of Biblical Archæology, vol. viii., p. 400.

† The Hebrew word for brick is *lebanah*. This also means "white." The term is also applied to the moon, owing to its whiteness. Rawlinson, in his "Herodotus," suggests that there was some connection between the word "brick" and *Sin*, the Babylonian deification of the moon, who was the God of Architecture. This would be a very interesting point, if it could be established; but I understand that it is as yet doubtful.

‡ Sun-dried bricks are called *khest* in Persian; the fire-baked bricks are *ajur* or *aujur*. In Afghanistan, *khist* is used for both burnt and unburnt bricks. *Gill*, with a hard *g*, is Persian for mud.

§ This recalls an old practice of Eastern architects, in constructing domes with pots, thus producing a considerable reduction of weight, and consequent diminution of thrust. A well known example of this is the dome of St. Vitale, at Ravenna.

‖ *Strabo*, B. xvi., cl. 5. See also B. xvi., ciii. 10.

could construct such roofs. If there was any irregularity in the plan of the house, the barrel roof was extended or drawn in, as the case might be, to cover the space. Of course in the villages it was all a very rough and ready kind of work, evidently done by no better principle than that of rule of thumb. I was still more surprised when I learned that these vaulted roofs were constructed without centers. I can suggest so far how this is accomplished. Their bricks are said to be about eight inches square and only two inches thick; this gives a large flat surface and not a very heavy brick for its size. They place these bricks, not perpendicularly, but at an angle, so that the one rests partly on the other, and by the use of a little *gatch*, or gypsum, which is plentiful in Persia, they can be made to adhere till the key-brick is put in. Perrot and Chipiez give a drawing of an arched conduit at Khorsabad,* where the bricks are shown in the construction almost similar to that which I have just described, and I feel sure that these conduits were also made without centers. In describing the construction of these conduits, the writer says: "We may believe the notion of building in this way would never have occurred to the Assyrian architects but for their habit of dispensing with timber centers."

As the possibility of forming a vaulted roof without centering may be new to many in this western part of the world, I shall add further evidence, which is supplied by Perrot and Chipiez. They say: "We may

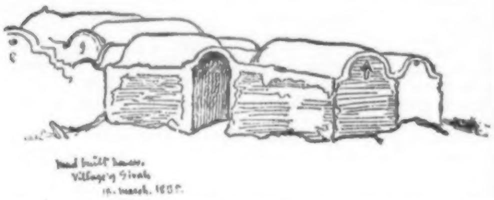


FIG. 2.—MUD-BUILT HOUSES, VILLAGE OF SIVAH, KHORASSAN.

refer those who are especially interested in constructive methods to M. Place's account of the curious fashion in which the workmen of Mossoul will build a pointed vault without the help of any of those wooden centerings in use in Europe. In our day, certainly, the masons of Mossoul use stone and mortar, but their example none the less proves that similar results may once have been obtained in different materials. A vault launched into mid-air without centering, and bearing the workmen who were building it on its unfinished flanks, was a phenomenon calculated to astonish an architect."† Rich gives details of a similar method, which is practiced in Bagdad. It is also affirmed that the Byzantine architects produced arches, if not domes, without the aid of centers. M. Place‡ describes one method of making vaults without centers, which he saw in Kurdistan, and in this case they were women who performed the operation. They placed rings of dried clay, each smaller than the other, till the dome was completed. The evidence of these authorities, added to what I learned in Persia, would seem to establish that this was the practice over all the wide space from the Mediterranean to Central Asia.

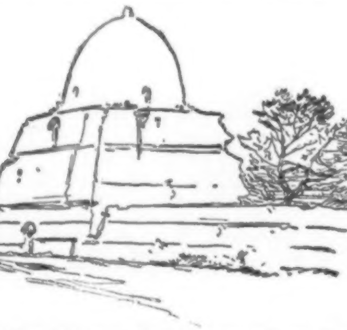


FIG. 3.—TOMB, CONSTRUCTED OF MUD, WITH DOME.

In Persia the mud walls are covered over with a mixture called *kahgill*,§ which is composed of mud and chopped straw; this serves to prevent the rains from washing away the walls, as it hardens the surface. The application of this mixture is generally repeated every two years.

Thus far, I have been dealing mainly with details of construction, and with ordinary dwellings. The general impression in most minds will no doubt be that mud building only belonged to a rude condition of civilization, and produced houses that were little better than hovels. I have now to point out that this manner of building was developed into a highly decorative style, which, in itself, would entitle it to a place in the history of architecture. This position, it appears to me, has been almost entirely overlooked by those who have written histories of architecture. Architectural writers always treat upon primitive wood constructions, because forms can be traced from them up to the highly developed styles of Greece, Egypt, and India.

The same process can now be gone through with the primitive mud as a building material. Before I have done, I shall point out architectural forms which owe their origin to this source. At present my purpose is to show that it was carried to a pitch of finish and refinement that rendered it worthy for the palace or the temple.

The following letter sent to me by General Sir Charles Wilson would, in itself, be a sufficient evidence. Sir Charles is well acquainted with Western Asia, and being an engineer officer, he may be trusted as an authority. He says:

"It may interest you to know that in Anatolia there is much mud building; and that most of the great buildings of the Seljuks, more especially their great palace at Konieh, were of mud faced with glazed tiles. Some of the minarets of their mosques, built with sun-dried bricks, arranged in patterns and faced with glazed tiles, or with the ends of the bricks glazed, are extremely beautiful in their decay. The Seljuk architecture is Persian with a development of its own."

Here are mosques, or temples, and a palace constructed with sun-dried brick, which are declared by this high authority to be beautiful even in their decayed condition.

A somewhat similar development was reached in Peru, but with different materials. Squier, in his "Land of the Incas," describes the palace of Chimu, where the *adobes* or sun-dried bricks were covered with stucco, on which beautiful arabesques were produced in relief.* From these ornaments he calls one of the great apartments the "Hall of Arabesques;"* of which he speaks in warm admiration, and adds: "No description can give an idea of the character of these *relievos*." In describing other ornamentation of the same kind, he says, "Here, as elsewhere, there are traces of color."†

I understand that the higher developed condition of this style of architecture in Persia was attained by covering the mud walls with glazed tiles. The tiles, it must be understood, were covered with ornament. Those who are familiar with the artistic qualities of Persian tiles may be able to form some idea of what could be thus produced. I regret to say that I saw very little of it. The part of Persia through which I passed had been so utterly devastated by the Turkoman raids, scarce a vestige of anything ancient remained. At Meshed, only, I saw a gateway, built with sun-dried bricks and covered with ornamental glazed tiles, but it was a very poor specimen of art; yet it told me what might be done in this style if the work could be put into the hands of real artists. Meshed is celebrated and is a well-known place of pilgrimage, from its having the tomb of the Imam Reza in it. The shrine is said to be decorated with some very fine tiles; but the whole inclosure, which is in the center of the city, can only be entered by the faithful.

The interior of a mud building may also be decorated with glazed tiles; but in Persia *gatch*, or gypsum, is plentiful, and where ornament is required it is much used. In an old tomb, at Sarrakhs, I saw some particularly good ornament in this material; and it appeared to me to be all hand work. I chanced to come upon one room that impressed me with the capabilities of this manner of decoration. It was at a place called Mazinan, on the first march eastward within the Khorassan frontier. There appeared to be the remains of more than one town here; I strolled over to that which was nearest and found that it was all formed of mud. It was rough work scrambling over the heaps, but at last I reached a mass that had probably been the *arg*, or citadel, and here is the description I jotted down at the time, immediately after the visit:

"It was with some difficulty that I was able to climb to the top, as the mound had been used as a quarry—a mud quarry—of the building material of the region. The mass forming the mound was artificial, for I found bits of red burned bricks or vessels embedded in it. The top was a curious maze of rooms, courts, stairs, and roofs, much of it in a tumble-down condition, and it was rather difficult to find a way in places. From the superior finish of some of the rooms, I concluded that a governor, or some important man, had lived in this place of security, but there were ruder additions, which showed that servants, or perhaps a more simple kind of people, had in all probability used some part of the place at a later time. The solid mass of mud or earth was about twenty feet high, and the houses were above that; still they were not all on the same level, for I went up and down short flights of steps. The whole was of mud or sun-dried bricks. Here I found, at least, one illustration of what can be done with such material which, from the high finish it presented, was rather a surprise to me. It was the best room in the place; the dimensions were small, somewhere about fifteen by ten feet. The lines of the interior were all perfectly straight, and at right angles to each other. The best houses in London are not more exact or more finished in their details than what I found here. The mud must have been carefully put on at first, but the high finish was produced by *gatch*, or gypsum. There were very handsome niches all round the walls, and the fireplace had been elaborate, but some act of destruction had taken place, and the fragments lay on the floor where they had fallen. The ornament was simple, there were some slight mouldings on the space between the niches. Lines had been drawn into the gypsum, and an ornament had been repeated by means of a stamp which had been pressed or imprinted when wet, producing a raised pattern; the impression left was so clean and perfect it might have been gilt, and it would have been quite equal to the work we have at home on picture frames. The contrast between this highly-finished interior with what was outside was very striking."

It was from what I thus chanced to see, even in this desolated region of Persia, that it began to dawn upon me what this peculiar manner of construction really had been. It was the exclusive building material of that part of the world. The simple houses of the villages are formed of it; the defensive walls of the towns, and which, owing to the Turkomans, were an absolute necessity to every village, were constructed of the same. The houses of the rich were also formed with it, and it had been developed into a highly decorative style of architecture; all this grew upon me, and I felt that this peculiar manner of building had not received the attention of writers its merits have entitled it to.‡

One would not expect much durability from such walls, yet I was informed that there are walls of sun-dried brick in Ispahan which are over 300 or 400 years old. This quality of durability will no doubt depend upon the character of the soil. About Tehran the earth is sandy, while at Ispahan it is said to be more adhesive. In the northern part of Persia, according to Mr. A. Finn, of the consular service, the walls of the old city of Erig are still standing, and they are said to have existed for 1,200 years. There still remains at Cacha, in Peru, a wall of *adobes*, or sun-dried bricks, part of the temple of Viracocha, which was in a ruined condition about three centuries ago, when Garcilasco described it, and this wall is still standing to a height of 40 feet.*

There are the remains of very old walls in Egypt. Maspero describes one at Abydos, called "Kom-es-Sultan," or "the Mound of the King," an old fortification, where part of the crude brick wall still stands, "from 24 to 36 feet high."† Maspero does not give a precise date, but from what he says, I understand that he places the origin of this fortification as far back as the earliest of the dynasties. These examples are sufficient, although others might be cited, to show that mud walls need not be mere things of a day, and that they have in the past endured for centuries. There is a Devonshire saying regarding the "cob," or mud walls, of that locality: "A good hat and a good pair of shoes is all that cob wants." The pair of shoes here meant is a stone foundation such as I have described in the Persian houses; that is, to protect the lower part of the wall; and the hat is a sufficient amount of thatch, or covering, to the top of the wall to save it from the influence of rain. With such conditions, I believe that mud walls in Devon, even in our own damp climate, have stood for long periods of time.

I come now to one very interesting part of the subject connected with this peculiar style of building, and that is to point out a few architectural forms that can be traced back to it. The history of no architecture can be accepted as complete till every form in it has been followed through the past to its first origin. This has been fairly well done in Greek architecture, where the main features of it have been traced back to wooden forms. Many of the details of Egyptian and Indian architecture have also been shown to have had a similar derivation. In these details the wooden character has been so distinctly continued in the lithic reproductions, that the evidence may be considered as complete and reliable. In the material we are now dealing with the forms are not so well defined, and the mutation from one material to another having taken place far back in their history, we have not the same trustworthy evidence to present regarding it. Yet, in some points it is fairly good, and in others we have every probability to support them.

The sloping jambs of doors and windows are peculiar to many old styles of architecture, such as the early Greek and Etruscan. Theories of origin for this have been often suggested, but we have no difficulty in accounting for them, if we suppose that the narrowness above was a form, and the natural result of the sloping walls of mud. The wooden parts of the first Greek temples were the portico and the wooden frame to support the roof; the walls of the cella were in all probability, of crude brick. The late explorations at Olympia have led to an idea—but which still requires further support—that the cella of the Heræum at that place had been constructed of mud. This is the temple of which Pausanias states‡ that one of its original wooden columns still existed in his time, which is an evidence in itself of its great antiquity.

I have already explained how builders in mud—and which is well exemplified in Persia—construct their walls with a broad base, to give solidity below, and with a marked batter upward to reduce the weight above. It has been suggested—and, I think, with every reason in its favor—that this explains the very marked slope of the perpendicular lines of the Egyptian pylons. All the authorities agree in stating that in the old temples the outer wall forming the temnos of temples of Egypt was made of crude brick, and as the pylon was the gate through this wall in front of the temple, the great probability of its being constructed of the same material is obvious.

At one time the Romans were credited with having invented the arch. Later, it was supposed that they only derived it from the Etruscans. At the present day no one would venture on locating the discovery of this constructive form with any one particular people or country. It is now known to be so old in Egypt that its first beginning there cannot be determined.

Vaulted and domed structures—such being principally used for granaries or storehouses—are also very ancient. The same may be said of Mesopotamia. Domed buildings are represented in a sculpture from Kouyundjik. M. Place's excavations at Nineveh show that the palaces there were roofed with vaults of crude brick, covered with stucco. Long ago Mr. Fergusson reasoned out the probability of this from the plans of these buildings. The Chaldeans constructed vaults and domes two or three thousand years before our era, and M. de Sarzec's explorations at Tello have raised the supposition that the Proto-Chaldeans were capable of accomplishing the same kind of roofing for their houses.

When I had seen village after village in Persia with vaulted or domed roofs, and learned that such roofs could be formed without centers, the idea immediately suggested itself that these methods of building had existed from the most primitive times; and this supposition finds strong support from the results of recent explorations in Egypt and Mesopotamia, which have just been referred to. While the necessity for wooden centerings for building vaults and domes was believed in, we never could have credited an early state of civilization with this invention. Let this assumption regarding centers be removed, and the whole pro-

* See a *Hist. of Art in Chaldea and Assyria*, vol. 1, p. 232, Fig. 93. See also Fig. 92, p. 229.

† *Hist. of Art in Chaldea and Assyria*, by Perrot and Chipiez, vol. 1, p. 167.

‡ *Ninive et l'Assyrie*, vol. 1., pp. 266-267. The Church of Mousta, a town in the center of the island of Malta, was built in the present century by the local masons; and they constructed the dome—said to be the third largest in Europe—without centers.

§ The word is *kah*=straw, and *gill*=mud. In Indian villages the mud floors are washed over with a thin mixture of mud and cow dung.

* *Peru, or the Land of the Incas*, p. 135.

† *Ibid.*, p. 154; also at p. 411.

‡ It has not been altogether overlooked. I learn that it has been dealt with in more than one work. M. J. F. Blondel's *Cours d'Architecture Civil*, Paris, 1777. His editor, Patte, gives a description of the mode of constructing buildings "toute on terre dite pise." It is treated upon in a work, published in Berlin, written by H.F. Rodlich, entitled *Praktische und historische Darstellung Erdbaukunst*. There is an article on "Pise" in the *Dictionary of Architecture*, Arch. Publication Soc. Miss Yule, in Murray's *Handbook of Greece*, gives some very valuable references to it; and I would refer all who are interested in the subject to look up the *Quarterly Review*, vol. lviii., 1837, for an article "On Cob Walls," by Mr. Richard Ford, the father of Sir Francis Clare Ford, our ambassador at Constantinople. It is a very learned article, and, at the same time, very amusing. I may also refer to a paper, read by myself to the Royal Institute of British Architects in 1887, on "Mud Architecture," and published in the *Transactions* of the Institute for that year.

* Squier's *Peru*, p. 407.

† *Egyptian Archæology*, by G. Maspero, p. 17.

‡ *Pausanias*, B. v., c. xvi.

blem is changed. The earlier workers in mud or clay could not have been long in discovering how to spread their material over the space inclosed by four walls. They would, no doubt, have begun at first with small spaces, and a very little experience would soon have enabled them to deal with greater. If any one considers the matter, I think he must arrive at the conclusion that mud must have been first used for a long period of time before burnt brick came into existence; and now that we know how easy it is to produce a roof with the mud, there is no great improbability in the assumption that the vault or dome, as well as the arch, all date back to a period when that material alone was in use. This also means that it was in a region where wood was scarce; for the existence of wood must have had in itself the tendency to prevent the invention of the vaulted roof. I do not suppose that the vault was invented in one region and was afterward carried to another. My idea is that, wherever the conditions that I have described existed, such a mode of producing a roof would be arrived at. Whatever may have been the case, it occurred so far back in the history of our race that I fear the exact date is likely to remain as one we can only speculate upon. My own conclusions, which can pretend to nothing more than that of inferring what may have been probable, is at least based on our latest knowledge. Further explorations may give us more light and more certain data to reason upon.

Let me here direct attention to a very important development, in fact, to what might be called a complete change in architecture, which can be traced back to this origin of the arch, the vault, and the dome, which have been followed back to their first origin. The origin, I frankly admit, is theoretical, but it is a theory with much in its favor. Greek architecture was what is technically called "trabeate," that is, with columns supporting a lintel or architrave. This style originated from wood, and was, by means of the conquests of Greece and Rome, largely diffused over the old world. The change which occurred was that of the pier supplanting the column, of the arch doing duty for the lintel; the vaulted roof and dome at the same time taking the place of the straight-lined roof and pediment. This important change in architecture was, in fact, nothing less than the forms of mud origin supplanting those forms that had been derived from wood. The style to which this mutation is attributed is that known as the Sassanian, which belongs to the period when the dynasty of that name ruled in Mesopotamia. There are very few remains of this architecture left,* but in these few we find the arch, the vault, and the dome, combined into a full-grown architectural style. The rise of Byzantine architecture may have been independent, but it was nearly contemporaneous with the other, and was probably influenced by it. When the Mohammedans destroyed the Sassanian power, they seem to have adopted the architecture, for the arch and the dome became the principal features of the Saracenic style, which they carried westward to the shores of the Atlantic and into Spain.

Not only did this style influence the architecture westward, but I am now in a position which enables me to trace it eastward as well. Major Talbot, R.E., one of the officers of the Survey Department, with the Afghan Boundary Commission, chanced to visit a place called Haibak, which is on the main road from Kabul to Central Asia; it is to the eastward and not very far distant from the site of the ancient city of Balkh. There are numerous caves in the locality, and as they are near to Bamian with its city of caverns, their Buddhist character may be assumed. Major Talbot luckily made very careful plans and sections of one group, known as the "Stables of Rustem." These he sent home to me, and on inspecting them I found that some of these caves had domes excavated in the rock, and that they were imitations of constructed domes. But more than this, I saw that the domes were the same in form as the few still remaining to represent what Sassanian architecture had been. One of the details which fully determines this is the pendentive, by which the square form of the plan is converted into the round as the base of the dome. These are exactly the same in the Haibak caves as in the Sassanian domes. Major Talbot, by good luck, sent me a sketch of a pendentive in one of the Bamian caves, and it is similar to the others, showing that the Haibak examples were not exceptional. As these domes were exact copies of structural ones, they prove most distinctly that the Sassanian style was not limited to Mesopotamia, but must have extended eastward all through Persia and Khorassan to Central Asia. This discovery necessarily gives a new value to the Sassanian mode of construction, which has been known up to the present from about only half a dozen ruined monuments that have been left to us. A question is opened up by this new aspect of the case: that is, did this style first originate on the banks of the Euphrates or in Central Asia, both of them mud-building regions? This cannot be answered at present. The great probability is that it might have been contemporaneous along the whole region. Now that we know the Sassanian style existed so far east, it becomes evident that it was the architecture carried at a later date by the Mohammedans to Afghanistan and also into India, where it became the parent of the Mohammedan style in that country, and produced those beautiful musjids and tombs at Delhi and Agra, which command the admiration of all that are lucky enough to behold them.

I have described the foundations of a mud wall, such as they are in Persia, formed of burnt bricks or stones and lime; and also in Devonshire, where they are known as a "good pair of shoes," because they protect the feet, or lower part of the wall. In the remains of the temple of Viracocha, in Peru, the mud walls there have a stone base eight feet in height. With these examples before us, and understanding the necessary purposes they served, we may assume that such protective substructures were generally employed wherever this particular manner of building was in use. It is highly probable that in this rude constructive detail we have the first origin of the part of the architecture in the palaces of Assyria to which the great winged bulls in the British Museum belonged. It seems now to be accepted that these palaces were constructed of crude brick, or at least this material was the principal one employed; baked or perhaps glazed brick may have been used in the exterior of the walls, but the interior was of sun-dried brick, and covered with stucco.

This latter part is exactly what I saw in Persia, and have already described in this paper. Along the base of these walls slabs of marble were placed, varying from three to about eight feet in height. These were generally sculptured, and the great bulls were represented on the portions of the slabs on each side of the doors. The development of this highly ornamental dado in the palace, from the base of the mud wall, is not a difficult problem to solve. The foundations I saw in the villages were formed of stones, half bricks, or rubbish of any kind. In the better class of houses a more regular construction would be followed; and in palaces the covering of this with marble is what might be expected. I accompanied a visit of ceremony to the palace of one of the Shah's sons in Tehran, and I noticed that, in the room where we were received, slabs of alabaster, about three feet in height, went all round the base of the walls. These alabaster slabs in Persia are the counterpart of the marbles in the palaces of Assyria. In both cases they served the same purpose—they protected the lower part of the walls.

It is not so long ago, in this country, that the dado commanded a large amount of what, at the time, was known as æsthetic devotion. From the interest then produced, I feel justified in pointing out that here I have given the origin of at least one dado, and that a very important one, as the sculptures in the British Museum make evident.

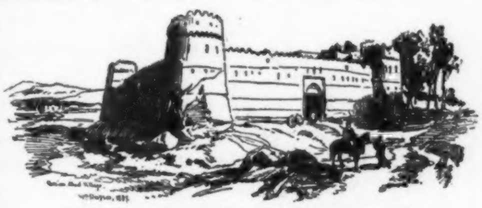


FIG. 4.—PERSIAN MUD VILLAGE.

I am inclined to suppose that the old masonry which we recognize under the word "Cyclopean," which is known to all who have any familiarity with the archæology of Greece, had its first origin as the base of mud walls. No direct evidence exists on which to ground this supposition, and I only present it here as a mere guess. We do know that Greek towns were, at an early period, defended by mud walls. In B. C. 385, Agesipolis, King of the Spartans, managed to take the city of Mantinea, by damming up the river till its water reached the base of the mud walls, which fell down as soon as their lower part was softened. Pausanias, writing of this siege, declares that such walls were, in one respect, better than stone: "Though a wall of this kind," he says, "stands the shock of warlike engines, and is a better defense than a wall of stone (for stones are broken in pieces, and leap from their places, through the force of these engines), yet it is dissolved by water, no less than wax by the sun."* As an evidence that mud walls of cities in ancient Greece were not exceptional, Pausanias may again be quoted. He says, regarding the method by which Mantinea fell, that "Agesipolis was not the inventor of this stratagem; but it was employed prior to him by Cimon, the son of Miltiades, when he besieged Eion, near the River Strymon."‡

These references show, not only that mud walls were common, but that for security a "good pair of shoes" was an absolute necessity in that early period, when Cyclopean masonry was practiced. This suggestion first occurred to me from Squier's description of the Temple of Viracocha, where the old wall of *adobes* stands on a base of Cyclopean masonry 8 ft. high and 5½ ft. thick. An illustration is given, which shows the exact character of the masonry.

It was a source of some surprise to me to find that the Persian villages were, as a rule, exactly similar to those I had seen in the Khyber Pass and other parts of Afghanistan. They are square, formed with four high crenelated walls, and a round tower at each corner. The gateway is in the center of one of the walls, and the mud houses are huddled together inside, one might say "anyhow." Larger villages may have six or eight towers; small towns or large ones have more wall, and a larger number of towers. One of the first things that drew my attention to mud as a building material in Persia was when, in passing a small town one morning on the march, I saw some men either building or repairing the walls and towers of the place. It then struck me that these defensive walls were, with only some trifling details of difference, almost identical with the walls we are so familiar with on the Assyrian sculptures. There is the same repetition of crenelated wall and tower, and constructed of the same material. I said to myself, "These men in the present day are building an old Assyrian wall of fortification." Such defenses must have begun at a very early date in Mesopotamia, long before the sculptures were produced from which we know what they were in appearance, and their construction has never ceased from that to our own time. This presents a very striking illustration of the continuity of type; and I confess that the discovery produced at the moment a very strong impression upon my own mind.

FIG. 5.—THE MUD WALLS OF NISHAPUR, KHORASSAN.

About one hundred miles east of Tehran there is a curious village called Lasgird * (Fig. 6). It is supposed to be very old, and its circular plan is said to have been first drawn on the ground by Las, the son of Noah. Not having heard of this personage before, I have been looking out for some reference to this member of Noah's family, but up to the present without success. The statement has already been made that the villages in Persia are square. Such is the rule, and it will explain so far how a round one in their midst appears as something strange and remarkable. Imagine a huge rough cylinder of mud standing up, perhaps 30 feet or more in height, and covering a space about the size of that inclosed by the railings of Leicester Square. (These are only eye guesses as to dimensions.) This great circular wall is so massive that the houses of the people are constructed on the top of it, and form in a rather irregular manner two stories. There are rude balconies, or I ought so say narrow ledges, on the outside, which form communications. These are made of untrimmed branches of trees, interlaced with twigs, on which mud is laid, but without a protective railing of any kind. Goats which I saw on these frail and dilapidated ledges were safe enough, but children, that I also noticed at play on them, seemed doomed, sooner or later, to certain destruction. The interior space formed by the circular wall is filled with storerooms and places where the cattle can be safely housed in case of an attack from the Turkomans. The only entrance into this strange structure is by a small opening about 4 feet by 3, which can be closed by a stone door turning on pivots. The smallness of this doorway was intended to prevent raiding enemies from entering during the chances of a rush, for it would be necessary to keep it open to the last moment to admit those of the villagers who were running home for protection. I noticed small stone doors in many places, and the purpose they served was that they could not be

FIG. 6.—LASGIRD.

* Among the few may be mentioned the Takht-i-Khosru, at Ctesiphon, and the palaces at Feruzabad and Sarvistan.

* *Pausanius*, b. viii., c. xviii.

‡ *Ibid.*

* *Gird* in this word is said to have the same significance as "girdle" in English—which may be rendered as "circle." [This block has been kindly lent by the editor of the *Illustrated London News*.]

destroyed by fire;* the raiders had no time for regular siege operations. They made a rush upon a village, and caught all, man or beast, that were unlucky enough to fail in reaching the shelter of their mud walls.

I have dealt with this building material in the past; regarding its future I can say but little. In England here it was largely in use, so was wood, and that which is well expressed by the words "wattle and dab," which might be described as a combination of wood and mud. All these, as our material conditions have improved, have been slowly supplanted by burnt brick or stone. "Cob" is still in use, to a limited extent only, in North Devon. It may be assumed that it is not suited for our damp climate. In dry climates, as Persia and Egypt, it is likely to continue, for the simple reasons that it is a cheap material and that a comfortable dwelling can be made from it. It might be utilized by some of our emigrants. Australia is reputed to be a dry country, and it might be employed by first settlers, particularly where wood is scarce. An emigrant, if he had a few hints and suggestions to start with, could easily construct a house for himself, and it would have one great advantage over a wooden house—it could not be burned down. I have already mentioned in this paper how an officer at Jellalabad made a very comfortable hut for himself. What he did there an emigrant might easily do in Australia. The non-inflammable character of mud ought to be a strong recommendation of it in many parts of the country. I might mention a country like California as one where this material might be valuable. California has a dry climate. When I was in San Francisco, in 1873, that town was almost wholly constructed of wood. Stone was feared, owing to the chances of earthquakes. While there I visited the Church of St. Francis, built of *adobes* a century before, and it had stood firm and secure all that time. It occurs to me—but I have no right to speak as an expert—that a house built of

FIG. 2.—STONE DOOR, LASGIRD.

thick mud walls and wooden joists and rafters would be tolerably safe during an earthquake, unless it was a very severe shock: such a house would also be safer than a wooden one from fire, which has always been a great danger in San Francisco. I have only referred to California as an example; what has been said of it will apply to many other parts of the world, where it is possible this building material might be used with advantage even in our own day.

THE COLOSSUS OF RHODES.

THE annexed illustration, taken from "Prometheus," represents the gigantic statue of Apollo at Rhodes, according to the engraving made by Athanasius Kircher, who published a work on the tower of Babel, and other large buildings, statues, etc., in the year 1679.

Although no reliable information regarding the form of the statue is obtainable, it is reported, however, that it was about 100 ft. high and required 36 tons of metal to cast the several parts of which it was composed.

The hollow legs and body were filled in with stones after the completion of the statue, so as to give it greater stability.

The reconstruction as given by Kircher must not be accepted as absolutely correct, yet it shows the possibility that the spread legs with their high foundation formed the entrance to a specially built up inner harbor.

The foundation bears the legend that Chares, the disciple of Lysippos, was the architect.

Chares died before the statue was completed, and the work was finished by his friend, Laches, in 280 B. C.

The statue was not only a mere ornament for the port, but was utilized as a signal tower for marine vessels, and for this purpose a flame was kept continuously burning in the torch carried in the left hand of the sun god.

The stone filling did not prevent the shattering of the statue during the earthquake in the year 224 B. C.; so that it only stood as guardian over the port for the short period of 56 years. The immense fragments of the statue remained undisturbed for nearly 870 years and were carried off at the time the Arabs took possession of the island. Their chief, Othman, sold the metal to a Jew, who, it is reported, required 900 camels to carry off the fragments. T. G. H.

THE COLOSSUS OF RHODES.

THE LADIES' CONVERSAZIONE OF THE ROYAL SOCIETY.

THE ladies' *Conversazione* of the Royal Society took place on the evening of June 15 last, and in every way was a distinct success, the attendance being the greatest on record, and all the available space, both for the guests and exhibits, being fully occupied. The exhibits, although they included a few that were shown at the last *soiree*, were for the most part new, and the following, for which we are indebted to *Nature*, is a brief summary of the most noticeable of them:

Dr. H. Hicks, F.R.S., showed the remains of a mammoth found in Endsleigh Street, in March last, at a depth of only 22 ft. The bones were of enormous proportions, and in their proximity was discovered a tusk which was estimated to have been 12 ft. in length.

A series of enlarged transparent sections of the fossil plants of the coal measures were exhibited by Prof. W. C. Williamson, F.R.S.

Most interesting were the water color drawings of Greek temples, etc., by Mr. F. C. Penrose, which illustrated his current investigations on the astronomical orientation of ancient Greek temples. The drawings included those of the Propylæa, the Temple of the Wingless Victory, Parthenon, west and east fronts of the Parthenon, north portico of the Erechtheum, east portico of the Theseum, and the Temple of Jupiter Olympius.

Mr. W. M. Flinders Petrie showed some excellent water color drawings of the pavement which he has recently discovered in the Palace of Chuenaten at Tell-el-Amarna (1400 B. C.) during his recent excavations. This pavement is quite unique in Egypt, and is especially valuable, owing to the marvelous treatment of the plants depicted.

The water color sketches exhibited by Prof. F. W. Oliver (for the Scientific Committee of the Royal Horticultural Society) illustrated some typical examples of the damage done to plants by London fog. The injuries shown, he said, were exceedingly prevalent among cultivated hothouse plants in the London district during this kind of weather, and extended to a considerable distance from the metropolis, cases occurring as far as Cooper's Hill and Dorking. The sulphurous acid of the fog seemed, in many cases, to have acted directly on the living substance of the foliage and leaves, producing these lesions, while in others there seemed to have been evidence of an accumulative action of the deposits of sulphuric acid.

Mr. W. Crookes, F.R.S., who at the last *soiree* repeated some of Tesla's wonderful experiments, exhibited a novelty in the form of burning nitrogen. He employed an electric current of 65 volts and 15 amperes, alternating 130 times a second, passing it through the primary of a large induction coil. From each of the secondary poles, flames became visible, and met at the center, being composed mainly of burning nitrogen. When the terminals were separated, so that the flames could not strike across but were in consequence extinguished, it was found that by putting them nearer together a lighted taper was sufficient to reignite them. The temperature of the flame exceeds slightly that of a good blowpipe, and a spectroscopic examination of the flame itself shows simply a faint and continuous spectrum. Mr. Crookes pointed out that such a method of exciting an induction coil was first employed by Mr. Spottiswoode in 1880, but "it is not known, however, that any chemical explanation of the flame has before now been published."

Mr. A. A. C. Swinton showed some very interesting photographs of electrical discharges that had been obtained by simply causing the discharges to take place across the surfaces of prepared sensitive dry plates, and consequently without the intervention of any lens. The distinctive character of the figures by the two kinds of discharges was very noticeable, so also was the evidence of their oscillatory nature.

Other electrical exhibits were:

An ingenious device for disconnecting the supplier of electricity if a dangerous voltage happened to be established in a house, and a leakage indicator for high tension currents, both exhibited by Messrs. Drake and Gorham.

Electrical discharges over prepared surfaces, by Mr. J. Wimshurst, showing that over imperfectly conducting surfaces of large area branch-like forms of flashes are produced, and with a great difference of

* The stone doors which are found so plentiful in the Hauran are formed after a wooden model, implying that wood had been the material at one time. The purpose of the stone doors in Persia makes it probable that a change at one period had taken place in the Hauran; unsettled times had come, and the doors had to be changed from wood to stone, to prevent burning, and thus give safety from sudden attacks.

potential sparks of seven feet in length can be attained.

High tension electrical apparatus, by Mr. L. Pyke, for working a considerable number of vacuum tubes from one generating source, the tubes in this case being each connected with terminally connected inductors, themselves counterpoised against two external conductors connected to the terminals of the transformer.

The director of the Royal Gardens, Kew, exhibited a specimen of a double cocoanut (*Lodoicea seychellarum*), with illustrations showing its germination. This palm is tall and fan-leaved, and peculiar to two of the Seychelles Islands; its fruit weighing from 25 to 30 pounds. At the germination of the seed, "the embryo is gradually pushed out of the seed by the growth of the seed leaf (cotyledon). One end of this remains attached to the seed, and conveys to the embryo the nutriment derived from the gradual absorption of the endosperm." Three of the drawings and a model had an additional interest in that they were made by the late Major General Gordon.

Mr. Romanes' exhibits of living rats and rabbits attracted much attention, and would perhaps have attracted slightly more if any of the former animals had by chance got astray. They were illustrative of some of the results of experimental breeding with reference to theories of heredity. The examples clearly showed that the male and female elements did not *always* so blend together that the offspring presented characters more or less intermediate between those of the parents, but that the progeny sometimes took wholly after the father or wholly after the mother.

Another animal exhibit consisted in a living specimen of a remarkable non-venomous South African snake (*Dasypeltis scabra*), from the Zoological Society of London. The animal lives solely on birds' eggs. Each egg is swallowed whole, and by a muscular contraction of the gullet, its contents flow into the stomach, while the shell is rejected by the mouth in the form of a pellet.

Among the other exhibits we may mention the systematic and simple construction of the dark absorption bands A, B, and *a* in the solar spectrum, after Mr. Higgs' photographs, by Prof. A. S. Herschel, F.R.S.; the photographs of stellar spectra, including Nova Aurigæ, Arcturus, etc., by Mr. Norman Lockyer, F.R.S.; the photographs of leguminous plants for the determination of the fixation of free nitrogen, by Sir J. B. Lawes, Bart., F.R.S., and Dr. J. H. Gilbert, F. R.S.; and an ingenious instrument for measuring the thermal expansion of very minute solid bodies up to high temperatures, and tracing the volume charge of the silicates up to and over the interval of plasticity, by Mr. J. Joly, F.R.S.

The exhibit in the archives room, by the postmaster-general, was during the whole evening thoroughly appreciated, the Telephone Company's installation being the means by which the guests were able to listen to the music of Salammbo from the grand opera at Paris. Previous to the switching on of the opera, conversation was carried on with some of the officials at the Paris end, and the accuracy with which the peculiarities of the various voices were transmitted was little short of marvelous.

The lantern demonstrations also attracted considerable attention. Mr. Saville Kent and Mr. C. V. Boys, F.R.S., as at the previous *soiree*, both showed their photographic slides, those of the former dealing with coral reefs, etc., and those of the latter with flying bullets. Mr. Norman Lockyer exhibited some photographs taken both at home and foreign observatories illustrative of the application of photography in astrophysical researches. The slides included some beautiful photographs of stellar spectra and solar prominences, from the Paris Observatory; of the moon and Jupiter, taken with the large Lick instrument; of the nebulosity surrounding η Argus, photographed by Dr. Gill, F.R.S.; of the great February sun spot, taken in India and forwarded to the solar physics committee; and of the spectra of Nova Aurigæ and Arcturus, taken at Kensington. The most striking slide of all was that of the great nebula of Orion, taken by Dr. Common, F.R.S., with his five foot reflector at Ealing. The apparent brilliancy of the stars, and the wonderful tracery in the nebulous parts, appealed to the eye not so much as an image of a slide on a screen, but as a direct view of this beautiful object through the great telescope itself. The slides shown by Mr. E. B. Poulton, F.R.S., were illustrative of the methods by which the originally opaque wings of certain butterflies and moths had become transparent and usually scaleless; numerous stages in the generation of scales were also shown.

THE NEW EDUCATION AND THE NEW CIVILIZATION—THEIR UNITY.

THE ANNUAL COMMENCEMENT ADDRESS AT OHIO STATE UNIVERSITY, COLUMBUS, O.

By R. H. THURSTON, Director of Sibley College, Cornell University.

ONE of our always forcible and suggestive writers on economics quotes the revolutionary patriot, Pelatiah Webster, as saying, a hundred years ago:

"I conceive very clearly that the riches of the nation do not consist in the abundance of money, but in the numbers of its people, in supplies and resources and the necessaries and conveniences of life, in good laws, good public officers, in virtuous citizens, in strength and concord, and in wisdom, justice, wise councils and manly force."

A new education and a new civilization based upon it as its firmest foundation; perhaps, more correctly speaking, an education and a civilization one and inseparable, interwoven as warp and woof, united as the roots support and form union with the tree and its branches and their fruit, constitute the most impressive feature of modern life, and give most reason for thought and speculation to the modern philosophic historian and the student of economics. It is this modern phase of a steadily advancing progress that presents to us who are here gathered on a supremely important occasion, most interesting material for study and most important problems. The promotion of the best purposes and highest welfare of the nation in the directions indicated by Webster presupposes the solution of such questions as these: What is the purpose of education? How is it related to these highest interests of the people? How can we, who are more or less responsible for the proper education of the "industrial classes" especially, promote that education which will best meet the needs and the demands of the nation, and of its citizens individually? How does this duty of promoting the best education for modern times and modern life fit in with our duties as citizens and members of a fraternity in which the good of all is best consulted by aiding the individual in his endeavor to gain that life, that liberty, that freedom in the pursuit of true happiness which is the fundamental thought of the constitution of our republic?

The discussion of the basis of the new education, and of the source and the foundation of the newer life of the people, thus involves the consideration of the question, How may we, as citizens of this great fraternity of citizens, best promote the welfare of our city, our country, our fellow citizens, and aid in securing for all those privileges for which Webster and his brethren were ready to write a new history in their own blood? As we must define education as being the preparation of the individual for the best use of his life and for highest service to his fellows, a high standpoint and a broad view must be gained preliminarily to such discussion.

Every person born into this world has a complete and indisputable right to demand that every right path in life shall be open to him; that liberty shall be accorded to him to perform every and any act adjudged by the common moral sense of mankind to be right. The individual must be the judge of the direction which best suits him in his search for happiness, and the state and his neighbors, alike, must give him way, just so long as he infringes none of the equal rights of others. The struggle with those mighty forces of nature that confront us all, and which nations, as well as individuals, must battle against, that great and inevitable contest that tries us all and sifts us into our several fated paths and levels in life, is quite severe enough, at best, without artificial and unfair introduction of obstacles by one's fellows.

Privileges are always complemented by duties. There are, as I conceive, four great classes of duties that must be assumed by some or by all of the people, individually or collectively, whether with or without common consent, to insure permanence of the community, and the possibility of training its youth for their work in life:

1. Life and property are to be protected at all hazards at all times.

This supreme purpose of the law being unattained, no movement of the people, no plan of the citizen, in political, social, or domestic life, can be insured success.

2. The people must be provided means for supporting life and acquiring all that life implies, of gaining all that life can be made to yield to them of good. This means that all the essential industries must be organized and promoted to highest efficiency; so as to yield, through the application of the best powers of the nation and its maximum energy, the greatest returns.

3. The moral status of the individual and that of the nation must be improved and held at a high level; not simply because dictated by a pure morality, but also, and hardly less essentially, because it is only when a people consists of individuals possessing a keen moral sense and highest integrity that the highest life of citizen or nation can be attained. Business cannot be carried on where honor is not ever present, or is not recognized as the genius always essential to full success. Life can never be worth living where the Golden Rule is forgotten. Suffering can never be prevented or relieved where self-interest rules.

4. Wisdom, thought, intelligence, must be fostered and promoted by all practicable means. Lack of understanding quite as often as selfishness, folly more frequently than real wickedness, lies at the bottom of crime and of error, both of individuals and of nations. The want of education, and of an experience rendered fruitful by wisdom and thoughtfulness, oftener causes the failures in business, and the fading out of great industries, than lack of ambition or energy. Only high intelligence can reveal to us all that the world offers of highest good and of truest pleasure.

The opportunities of the citizen thus constitute the nation's need, and their care the duties of the State. The rights, the privileges, the possibilities of the people, as a whole, are the study of every real statesman, desirous of promoting the welfare of his country, the highest purpose of statecraft. Every honest citizen seeks the best interests of the community of which he is but one unit. Every educator looks to the promotion of the growth of that intelligence which is the essential basis of all advancement in manners, morals or material gain. From our standpoint, what seem to be the requirements, that a nation shall enjoy peace, safety, all reasonable comforts and privileges coming with civilization, and all those higher pleasures to which every human being has a right to aspire? I think it is easy to identify and to enumerate the principal among them.

The nation needs, first of all, an honest, earnest, intelligent—for its purposes—well-educated, well-trained and righteous people—a people skilled in highest degree in all the arts capable of providing for themselves every essential of an enlightened civilization, able to thoroughly protect themselves against every injurious condition of life, or any malevolent attack of enemies, domestic or foreign, and wise enough to govern themselves without self-irritation, and to provide in all possible ways for their own steady advancement.

The material needs of the nation include fruitful soil, favorable climate, with variety enough of both to permit the cultivation of all needed fruits and grains, and also all materials required in the arts and manufactures, the metals and all materials of construction. It needs space for growth, and time for self-improvement of its workers; and this means varied industries, including all the agricultures, all the arts of common life, and, no less, every industry that can be made to take root in the presence of wealth and flourish under the stimulus of the demands of the highest intelligence and of the most perfect culture of modern life. For highest efficiency, these industries must be distributed in such manner that each shall find demand and afford supply close at hand; and the education and training, technical or other, which must underlie the highest arts and most skilled of the industries must be provided at every large center of population. Manufactures should arise and grow and flourish healthfully in the midst of agricultural sections of the country, and every cultivator of the soil should be able to find a market for his product close at hand, in the crowded haunts of trade. All the skilled industries should be within reach of mutual aid and support; the fine arts and the distinctively so-called useful arts should be as closely related in their geographical distribution as in their economics; indeed, all the arts are useful, whether supplying clothing to the naked or pleasures of the eye to the lover of the beautiful; whether giving food to a nation or teaching its children a love of the good and the true; whether making a home for the family or educating its members in all that constitutes wisdom and learning. If there be any difference in rank, these last are the best, the highest and the most to be sought after. But those other arts, nevertheless, are the foundation upon which only we can build these. The essentially, practically, useful must always supply the substructure; and the more solidly built must be that foundation, the higher we build our æsthetic superstructure, and the loftier the life we would live. The builders of houses and the builders of brain belong in one guild; the makers of homes and the teachers who make homes desirable are partners in business. The man who swings the hammer; the woman who hears the music of his ringing steel from beside the vibrating beam of her loom in the factory; the child gathering up the emptied bobbins on the mill floor; the mother at home singing to the rhythm of the cradle; the miner, risking life and limb amid explosions of dynamite and the rush of irrupting waters; the brave fellow at the throttle on the engine rushing, by day or by night, with the speed of the winds, across the continent, life in hand at every moment; the soldier on duty on the frontier or amid savages, defending his country; the statesman making righteous laws; the teacher giving intellectual life to a people; all alike, farmer, mechanic, scholar or soldier, are working to one end—the onward and upward march of humanity. Give equal honor to all who do their best as best they can. The differences among them are largely God-given. His, after all, the credit for all.

The diversification of the industries and the specialization of knowledge, and of talent, as well, various talents applied to as various arts, are essentials of progress. Every State should promote just as many kinds of industrial activity as can be made to flourish within its borders; every city should attract all the skilled industries; fine art should be encouraged at every great center of trade or manufactures. Where the industries are most varied and where highest skill is found applied to highest art, there exists all the safety possible against the ups and downs of trade. It is the crude and unskilled industries that suffer with the ebb and flow of business. The producers of articles of pure art and of absolute luxury are more independent of "crises" than are the laborers unskilled in trades. The same principle is illustrated by our advancement in education. As we develop higher education, we also find ways of making wider and more completely specialized application of the elements of knowledge to the purposes of daily life and of bread getting; and the growth of educational methods is as well illustrated by the foundation of trade schools, and, as at the capital of Ohio, of normal schools for manual training teachers, as by the differentiation of university instruction. The mechanic and the agriculturist, no less than the philosopher and the historian, make applied sciences and special investigation the foundation of their highest accomplishments. Our task is thus to diversify the industries of production, of æsthetics, and of instruction in all knowledge, whether of the past, of the present, or of that future which we are all striving, each in his own way, to make better. Thus, we seek to encourage every art, crude or fine, to bring together in one neighborhood all intelligent and skillful workers in all the known arts and trades; to find ways of instructing the youth in both manual and mental culture, making both school and school shop useful in adding to the number of mind-directed hands and intelligently working brains. We prefer rather to send the tax gatherer to collect for the schools and colleges than for the prisons and the poorhouses. One of the most important and interesting movements of modern life is this substitution of the former for the latter classes of public institutions, through the cultivation and the application of intellect in all the industries which constitute the modern life of the nations. This movement has been one effected mainly through the action of the State; and thus we come, by a very natural process, in the course of this somewhat didactic discussion, to the consideration of the purpose of government and the duties of the State.

The *purpose* of every good government is to promote the welfare of the people, morally, intellectually, physically. The duty of the State is to do what, in the promotion of that welfare, the individual cannot himself accomplish alone. The first duty of a government is to *govern*. It is to make secure life and property of every honest citizen, to protect him in his endeavor to live in peace, to work where and how he may choose or may esteem most conducive to his best interests; to gain knowledge either for its own sake or for useful application in his vocation, to enjoy the wholesome pleasures of life, to accumulate the fruits of honest industry to any extent, to acquire independence, to educate his children and to fit them, if they have the qualifications, for a larger and better life than his own. The State must insure the safety, the permanence, the diversification of industries, the encouragement and preservation of good morals, the promotion of education and the dissemination of knowledge, not only as essential to the stability of the State by reason of the necessity of intelligence as a characteristic of the citizen, but also as no less essential to the equally important element of stability as found in the symmetrical and complete development of every fundamental industry. The educational is as essential as the industrial or the criminal code to the highest interests of the people and the grandest development of the nation; and technical education is as necessary a part of public instruction, in fact more so, in the simple preservation of the life of individual and of nation as well, than is the older primary school or the latest form of liberal learning.

The privileges of "life, liberty, and the pursuit of happiness" presume also assurance of opportunities to

gain the prerequisites. A nation accomplishes its purpose when, and only when, it insures peace, safety to life and property, and promotion of good morals, through its criminal code; security of the material interests of the people by promoting the permanence, growth, and diversification of their industries, through the operation of an equally carefully and wisely devised industrial code; and when it secures for every citizen the privilege of gaining that education which is essential to his future prosperity as admitting him to the great industries and fitting him to intelligently and healthfully enjoy the full measure of compensation due him for skill and intelligence applied to useful purposes, in which all are interested.

The "new education"—which is yet the old—is simply that advance in the application of these never-denied and long admitted principles of polity and of public policy which has come to be seen to be demanded as a consequence of the progress of the age in invention, in the arts, and in our systems of industry. Reading, writing, and arithmetic were once the all-sufficient education of every class engaged in industrial pursuits; to-day a college education is insufficient to meet all the demands of some of the professions, and special schools are established in every country and in almost every city. A few years ago, there were but three professions and three kinds of professional schools. To-day there are many, both of the professions and of the schools. The old education was mainly gymnastic; the modern is both gymnastic and immediately useful in the vocations of daily life; the old university was a home for those who were called by Izaak Walton "cloisteral men of great learning;" the university of to-day is a workshop of all the arts and sciences as well as of the literatures. It is the product of a growth, not of a new planting, however, and we may reasonably hope for indefinite further improvement, and more and more splendid fruitage, with the coming years.

The characteristic of the century has been the introduction of the so-called technical education: the instruction of youth in those elements of industrial education which will give a training in all that is needed to make the pupil capable of doing a man's or a woman's work in the world as a single unit in the complex system into which all our lives are interwoven. The older system of education was one of primary school education for the people, high culture for the wealthy. A century ago, it began to be seen that this curriculum must be broadened in the intermediate fields, and that it should include more of science, and more of culture, as well, for the citizen of whatever grade, and that applied science and systematic instruction in the skilled industries of highest class must be introduced by every nation that would make the most of modern developments in the arts. France and Germany were the first to take the practical initiative and to establish national schools of the arts and of the sciences, pure and applied, as well as of the literatures and the philosophies. Their statesmen were the first to see that nations could now only be made great and secure by the incorporation, with the "book learning" of earlier times, of all new sciences and instruction in all new arts demanding system and skill; and the results of their foresight and energetic action are hardly less striking than was, nearly twenty centuries earlier, the work of what John Draper calls "The Scientific School of Aristotle," at Alexandria, the inauguration of which was the first, and is still the grandest, event in the history of education, defined as to-day. These great statesmen saw what had been in the minds of other great men long before—that security in the mighty struggles among nations, to result in the survival of the fittest, presumably, could only be insured by the systematic instruction of the people in the work of the people, and to-day all nations vie with each other in this competition for the foremost place in the industrial race, in expanding educational systems to meet this demand.

But the new education is but the seen expression of the principles declared by the oldest educators of all races and of all civilizations. Aristotle inspired the teachers in the "divine school of Alexandria" with the true scientific method which is at the foundation of all progress in knowledge of whatever kind, and the great philosophers of that time and their works have been, ever since, the acknowledged progenitors of the modern man of science. Archimedes and Euclid, Eratosthenes and Hipparchus, led in the propagation of the systematic development, perpetuation and diffusion of true science and useful knowledge. Ptolemy Soter founded the prototype of the modern university in its most complete and symmetrical form. That was a greater work than was ever done by the mighty warrior after whom the university was named. Archimedes was an engineer; Hero was a mechanician; Euclid was the mathematician of whom it can be said, as of no other man, his works have never been overpassed; Hypatia expounded the doctrines of the philosophers; Ptolemy gave origin to astronomy, and Phalareus was the presiding officer of a true university. Comenius, centuries later, but dreamed of the reconstruction of this scheme; and Milton in his "tract on education," proposing to teach all the useful branches of knowledge, and Bacon prescribing systems for the "advancement of learning," only presented anew the new education which was still the old.

When the Marquis of Worcester urged the inauguration of technical schools and the formation by the government of trade schools, and when that wonderful mechanic, Vaucanson, gave his collections of models and machines and curious inventions as the beginning of the French "Conservatoire," the first of great modern schools of applied science, they were but doing their part toward the restoration to the body, from which they had been lopped during the intermediate monastic period, the right arm and hand of a symmetrical system. Des Cartes and Herbert Spencer, in their studies for a better education for the modern time, and Scott Russell in his plea, so eloquently made to the Queen, for an education for the people of England, were merely resuscitating the long-neglected but still living ideas of Aristotle and of Plato. And a modern university, like that of the ancient Greeks, includes and presumes instruction in all knowledge that makes the life of the time and underlies necessity, comfort, luxury, or labor, leisure, and self-improvement. The lapse of the middle ages and of our later times, until within the generation, almost, was simply failure to incorporate into the old scheme the newer knowledges and the later applications of knowledge of modern life.

We to-day, in our technical schools and in our departments of applied science, are simply remedying a neglect of our predecessors, making symmetrical and complete that structure which had been left without extension, and here and there in decay, for so many generations, while every phase of life was becoming richer and richer, and demanding more and more from the insufficient system.

We have, at last, once more come to see that Plato was wise in his day and generation, and for our own as well, and that the State should aid the people to secure a State university, in a similar but in a wider sense than that in which the regents of the University of the State of New York as yet define it, in something more than a stereotyped and crystallized form. Continuous change and steady progress must be an essential characteristic of any perfect form of education. That progress must have, as its first result, the constant and perfect adaptation of the whole university, from primary to final element, and from classic to technical and professional branches, to the requirements of every class and grade of citizen. The rich, no less than the poor, the scholar and the handicraftsman alike, arts and sciences, languages and literatures and all the philosophies must not only find place, but must be kept in place, and the whole system always adapted to the steadily moving world.

Any real education, new or old, must be such as best prepares the man, and the woman no less, for successfully striving for all that either may fairly and rightfully hope to gain from the world, and to find in life. It must cultivate the mental powers, give physical strength and endurance, supply wisdom and knowledge for application in all the fields of life work, offer special instruction and training where needed for the prosecution of those branches of industrial occupation which demand either higher education in the sciences or special knowledge of processes and methods of work such as cannot be subsequently obtained by the youth leaving his teachers behind him and going out into the world to take up his tasks; whether in the forum, on the bench, at the bar, in the pulpit, by the sick bed, or on the table of the operating surgeon; whether he goes into art or architecture, engineering or school teaching, building steam engines or cotton machinery, railways or canals, working at the loom or at the blacksmith's fire. The aim of the framers of the State university system, and its feeding and accessory departments, should be to prepare for a development of all the industries, the creation of intelligence, the encouragement of good morals, and a righteous distribution of moral, material, and intellectual good to all citizens, and as far as nature permits, in equal degree through at least equal opportunity. The greatest practicable diversification of industries, the widest distribution of knowledge, the most equitable distribution of wealth, moral as well as material, intellectual as well as ponderable, all and equally, should be the purpose of the builders of the nation's noblest structure. It is this reconstruction of the ideals of Plato and of Milton and of all great minds since the time of Aristotle, which we now see rapidly taking form around us. The real university is coming into being; the teaching of teachers, as well as the training of pupils for the real work of life, is one of the illustrations of the extent and completeness with which the old idea had been incorporated into the new and still more perfect form, in this later time; and that greatness of soul and largeness of mind which permits a public man to turn quietly away from the chair of the highest office of a great republic to do his part in the work of completing preparations for the extension of such a system, finds no more impressive illustration in the days of Alexander or Julius Cæsar, of the French revolution, or of American independence.* Framing the educational system of a people is a greater work than even the construction of its foreign policy, or the organization of its penal code. These are the highest duties of the state, and it is in this work that patriotism, statecraft, wisdom, and honor, find their noblest place. THE EDUCATION OF YOUTH IS THE BUILDING OF A NATION.

Where, we may next inquire, is the citizen to seek opportunity to do his part, and what are the privileges that he may claim? The upbuilding of a nation involves the assignment of duties to the citizen and the insuring of the greatest, the grandest, opportunities to every individual composing the mighty whole. The duties are those of individually and collectively promoting the purpose of national advancement, of sending suitable representatives to make and to execute the laws, of helping friends and neighbors and compatriots to make successful careers, to lead happy and contented lives, and to promote the general welfare in all possible ways. The opportunities which the citizen may rightfully claim, under our government—under all governments, in fact—are those which enable him to make his own career. He has the right to choose his own vocation, to pursue any line of industrial, professional, or other occupation that he may find best suited to his talent, and, if he have it, to his genius. He has a right to display all the intelligence, earnestness, strength, skill, integrity, and judgment that he may be possessed of; to strive for every good in life, to seize upon every opportunity to advance himself honorably and honestly; to buy and sell, to trade and barter his property and his labor as may to him seem best; to gain the full reward of his highest efforts and best endeavors. He has a right to more than this: He may claim fairly and rightfully, he should be allowed to claim confidently, not only this privilege of doing his best and of gaining his full reward, but more than this and above all this, that his neighbor and his country shall give him active and effective and fruitful assistance. We all have the right to ask that we shall be actively aided in our efforts to make the most of life, to secure its highest rewards by honest effort. Every one of us has the right to expect that the State and our fellows shall give our children opportunity to become intelligent, well informed, skilled workers in their various spheres and in all their progress through life; that the youth may enter upon his career prepared to compete on even terms with the whole world; that the family shall have a comfortable home if the father and the mother choose to strive for it; that the aged shall be insured against retreat to the poor house, when closing an industrious and honorable life. Opportunity to learn what is essential to our own success and to the prosperity of the nation; opportunity to labor profitably in any field of agriculture, trade, or manufacture; opportuuity to buy and sell our labor and the products of our labor with best advantage; opportunity to seek and to gain comfort and pleasure in every department of life and in all its seven ages; these are what the citizen may rightfully claim. Even the wealthy citizen has rights above and beyond those which he has exercised and has profited so splendidly by in his earlier years. He has the right to give his children that culture as well as that special education which their position in life makes it incumbent upon them to completely avail themselves of, in order that they may most creditably and usefully fill that position, that they may make their own lives fuller and richer, and that they may do most to encourage and aid the less fortunate. He has the right to reach out from his firm ground of vantage and rescue those who are still at the mercy of the winds and waves of fortune and perhaps sinking under their burdens. He may fairly claim the privilege of doing all the good work that he may aspire to perform and to the assurance that his wishes shall be respected if he dies before carrying them into effect. He may ask to be assisted in the performance of that duty which comes with wealth, of helping the poor, of promoting the great philanthropies of the world, of building for himself a monument in college, hospital, or school, which shall make his name honored of all men for all time. That city, that state, and that nation, which thus gives to its poorest citizen the opportunity to rise and to do his best, to its richest citizen the opportunity to make the best use of his wealth in aiding his fellows, will advance most rapidly in all that the patriot most desires for his country. Life and property will be there most secure, wealth will be best distributed, comfort and happiness of high and low will be best insured.

Education, among all the possible means of advancing this great work, is the first and most essential. Education is to life what apprenticeship is to the trade. It prepares the individual to do his part as a unit in the great system of social economy. If suitably provided, it is the complete and ample introduction to all that life can offer of labor, attainment, enjoyment, in whatever field the individual chooses. Few men learn more than one trade; few men can accept all educations; few can hope to gain wealth, leisure, or highest culture; but all may claim the privilege of entering into the path that leads upward, each in his own place. Modern life, what we call civilization, in its newer phases, is simply the outcome of exertion directed by such education as the people have. The new education is but the newest phase of the oldest and best recognized system. The philosophy of Socrates and the dream of Bellamy—if it should prove representative of anything in a future still beyond view—are but separated points in a continuous line. The civilizations of two thousand years ago and those of two thousand years hence are but the product of the educations of their times. The peoples will be what they are taught and trained to be, whether in the infancy or in the old age of the world. Emerson is grander than Plato in so far as education and knowledge, continued thought and enlarged experiences, make him greater. Grant and Sherman could handle armies and plan a campaign better than Alexander, or Cæsar, simply because they profited by the wisdom and the experiences of those great captains and of all who had planned and fought since their day. The greatest Greek and Roman rulers and law givers made modern law possible and recent statesmen wise, and Athens remains a teacher of youth in every department, and in every college of our time.

Plato and every great philosopher since his day recognizes the education of the people as the chief duty of the state; Aristotle set the example of cultivating every useful branch, and the Alexandrian school set an example to the modern university. All great thinkers have urged that the technical side of life be most carefully and fully represented in the educational system. All great nations have found the prescription one leading to the advancement of every element of prosperity. A great university is at once the type, the exponent, the promoter and the basis of all that is good and great in modern civilization. Modern life is but the product of an evolution originating with life itself. Homer, Milton and Shakespeare; Plato and Emerson; Hero; Da Vinci, Watt and Corliss; Solon, John Bright and Henry Ward Beecher; Washington and Abraham Lincoln: these are all elementary parts of one eternal whole. Their relative chronological position gauges the growth of the race. Homer's Iliad; Plato's Republic; Quintilian's Treatise; Milton's Tract; the works of Rousseau, of Richter, of Goethe, and of Herbert Spencer: all such are milestones of progress from the old education, which was the old civilization, to the new education, which is the new civilization; from all the old worlds to all the new. And, as time passes us on into the newer old education will progress and change with the times that are coming, as it has progressed and changed with the times that are gone. But its change will be changeless, in that it will always represent the latest, the highest, and the best possible basis and buttress of the State. Learning, hand in hand with Wisdom; the power to do and the ability to create; scientific attainments and talent for their fruitful employment; appreciation of art and literary culture; the university in fact, lie, one and all, within every real education, and all are needed that Learning may be "Pilot to the World."

* A reference to ex-President R. B. Hayes.

THE DUKE OF YORK SITS DOWN.

YESTERDAY afternoon, June 17, says the London *Daily Graphic*, the House of Lords abandoned for a few moments the dullness of agricultural holdings, and gave itself up to a brilliant ceremonial display. The Duke of York was to take his seat as a peer of the United Kingdom, and in anticipation of the ceremony a large number of ladies had come down to the House and lined the peeresses' galleries. Another noticeable change in the general appearance of the chamber was the addition of a third chair beside the throne, and the removal of the brass railings which surround the throne steps. After a brief delay, the Lord Chancellor entered the House as usual through one of the doors beside the throne, and took his seat upon the woolsack. Almost at the same moment the procession that was

leading in the new peer entered the House at the other end, and, marching past the bar, slowly moved up toward the woolsack. At the head of the procession was the Yeoman Usher of the Black Rod, followed by the Hereditary Great Chamberlain, in a brilliant scarlet mantle. Next came the Garter King at Arms, with his embroidered tabard, that put every other dress completely into the shade, and then the central figure—the Duke of York—accompanied by his introducers, the Prince of Wales and Duke of Connaught, all three in scarlet and ermine robes.

THE PRESENTATION.

The scene as the procession moved up the House, with the sun streaming in through the stained glass windows, and the bright dresses of the ladies in the gallery, was fascinating in its brilliancy. In his hand the new duke carried his patent of peerage—a formidable parchment, with the great seal attached. As he drew near to the woolsack, the Prince and his introducers bowed to the Lord Chancellor, who in turn raised the wonderful three-cornered hat that on occasions such as these is cleverly balanced upon the top of his full-bottomed wig. The Prince having presented his patent to the Lord Chancellor, the legal formalities of admission to the House were dispatched by the clerks at the table. First, one of the clerks read out the contents of the patent in a gentle monotone. Next, the Clerk of Parliaments handed an elaborately bound New Testament to the Duke and administered the oath. The swearing was followed by the signature of the roll of Parliament, and nothing then remained but to conduct the new peer to his seat.

TAKING HIS SEAT.

For this ceremony the procession reformed, passed down one side of the table, round the cross benches, and up the other aisle, and so past the woolsack to the steps of the throne. Here the young duke advanced alone with his father to the seat placed for him, and sat himself down. But no ceremony in the House of Lords is complete without three bows—and there was a serious difficulty in the way of yesterday's bowing. The Lord Chancellor, on the woolsack, had his back directly toward the new peer beside the throne, and the woolsack is not a seat that can be easily moved. However, Lord Halsbury did his best. Twisting himself round so as to get within as few points as possible of the young sailor behind him, he raised again the three-cornered hat. The duke replied. A second time the solemn bow was performed, then a third time, and the installation was complete. In the minds of several peers, however, there was evidently an idea that the youngest member of their House would take his seat on the bench reserved for dukes as well as on the chair set for him as a royal prince. In view of this possibility, the other dukes hastily cleared a space for their colleague. But after Prince George had shaken hands with the Lord Chancellor, the procession, with many more profound inclinations, swept out of the House.

Then came the comic business, if such a phrase may be applied to so august an assembly. Scarcely had the last of the ducal robes fluttered through the doorway before there rushed into the House, not, indeed, a clown and pantaloon, but a stage army of supers, dressed as nearly as possible to represent French cooks. The cooks hastily seized the chair and carried it off. Others hurried in with the railings that had been removed from around the throne, and while the House of Lords wearily turned to its legislative duties, the railings were forced back into their sockets, and the last trace of the brilliant scene was removed.

THE LIFE OF DR. PETER HENDRIK VAN DER WEYDE.

AN AUTOBIOGRAPHY.

IT is a true saying that every man is born in this world without his consent, and that the great majority of them have to leave it against their will.

In regard to the consent, I have only to say that if I had been consulted when and where I wanted to be born, I could not have made a better selection than the beginning of the year 1813 as the most suitable time, and the city of Nymegen, in the Netherlands, as the most suitable place to be born and to pass my boyhood in.

And so it came to pass.

Also, in regard to the selection of my parents, this could not have been improved upon. They might have been richer, but it is very doubtful if they could have been better. I would also have preferred to be an only son, of a father who was an only son of an only son, etc., for seven generations, so as not to be bothered with namesakes, one of which might have deserved to be hung, poisoned,* beheaded with the sword or with hatchet on block, shot to death, burned at the stake, guillotined, garroted, or electrocuted, as might be the fashion of the times.

Also this came to pass, as in a long list of ancestors I am the first who had three sons, each of which has again an only son.

Now for the reasons of my preference of time and place of birth.

The year 1813 was to be preferred because when I came to the age of intellect the battle of Waterloo had disposed of the first Napoleon, that great disturber of the peace of Europe, who was then safely bottled up on the island of St. Helena. A period of peace and prosperity began then for Europe, which was very favorable for the mental development of the rising generation.

Young as I was, I realized the blessedness of this peaceful condition of Europe, because I had often heard my father discuss with his friends the dreadful condition over all Europe, when the reign of terror in France upset not only the material interests but the minds of all the people, old and young; how his own education had suffered, and that, when he saw that not only the governing classes in France were butchered under the guillotine, but eminent learned men, like Lavoisier,† of whom he was an ardent admirer, were not safe from the persecution of the fanatics, he was in despair about the future fate of human society.

When the reign of terror fell, he married and took a vow that, if ever he was blessed with a son, he would make up in him what had been neglected in his own boyhood. He had collected a very creditable library and oil paintings, which abound in Holland, so that when I grew up I found all the books I could sigh for, and, in addition, in order to be impartial in regard to the cost of the two children (I had a sister eight years older than I was), every time my sister got a new dress or a new bonnet, he asked my mother what it cost, and then he gave the same amount to me, and told me to go to the next book auction and buy for that amount the books I should like to have.

In regard to the city of Nymegen, it is the most healthy city in the Netherlands, being, according to the tradition of the inhabitants, built on seven hills, like ancient Rome. The hills, however, are only recognizable in the names of some localities, and in the steep incline of a great number of streets, which in itself affords gymnastic exercise for the inhabitants. Some of the narrow streets are so steep, indeed, that, in order to make them accessible at all, they have been paved with stone steps; they are, in fact, public staircases, lined on both sides by houses containing small workshops or stores. The moderately steep streets are especially a delight for the boys in winter, when snow is on the ground, which, in that latitude, remains frequently without intermission for several months at a time. Then the boys have a high carnival with their sledges and coasters, at which enjoyments I was soon one of the leaders, as I later became also in skating.

The local circumstances there make these healthy amusements so attractive that they are not confined to very little boys, as is the case here, but even larger boys often enjoy them, especially the chain of sledges formed by each boy taking hold of the ankles of the boy behind him; the last one may lose his sledge, but this makes no difference. The cry is always: "Hold on!" At home the mother wonders why it is that the seat of the boy's pants wears out so soon; but the boy don't wonder, knowing, as he does, the hardships he experienced, when he was compelled to ride down the lower part of a long and steep hill, without a sledge.

The prolongation of the innocent pleasures of boyhood is chiefly caused in Holland by the milder climate there; the severe cold spells of the American winters, and especially the excessive heat of the summers, are unknown there; the development is slower, and early maturity is far more exceptional than it is in more severe climates. My personal experience is that when I arrived in New York, forty-three years ago, I was surprised to find that men apparently of my age were some ten years younger while some of them actually appeared older than I was. They are all dead now, without a single exception.

In the summer season Nymegen is for the inhabitants of the low lands of Holland, and especially for crowded Amsterdam and Rotterdam, what the Catskill mountains are for the inhabitants of New York. Its situation on and near a series of hills forming the extreme northwestern spur of the bluffs of the lower Rhine, where they enter Holland, gives it an aspect which may truly be called romantic, while the public parks, situated on the highest parts of the city, afford an extensive panorama over the bottom lands of the Rhine valley, through which the river winds its serpentine course, and may be followed by the eye, up and down the stream, for 40 or 50 miles. The view is similar to that at Council Bluffs, opposite Omaha, on the Missouri, which reminded me to some extent of the neighborhood of my native town, for which reason I remained there several days, so as to repeat the walks up and down hill of my boyhood. However, the difference is that in Holland the bluffs are well wooded, the preservation of the forests being carefully attended to, both by the government and land owners, while the bottom lands are studded with cultivated acres, orchards, and dikes to protect farms and villages. The pastures are mostly the bottoms of reservoirs, used for the double purpose to relieve temporarily the excess of water which the Rhine passes through Holland, during the spring floods, while it thus yearly fertilizes the soil.

The high state of cultivation there is simply due to two causes; first, that the country was settled two thousand years ago by an agricultural race, and that there was ever a dense population and scarcity of land, so that about every inch had to be made available by cultivation, and, where it was possible, more land obtained by draining lakes and swamps, which has been done so industriously by man. Since the last one thousand years more than one hundred lakes have been made dry and productive of food for the inhabitants. The last achievement in this line was the drainage of the Haarlem Lake, which was the center of an extensive inland navigation, like Lake Ontario on a small scale, and was successfully drained forty years ago, and offers now a tableau of thriving farms, while an island in its center became a hill.

At present the drainage of a much larger surface, the Zuyder Zee, an inlet of the ocean, is contemplated. One of the problems to be overcome here is the disposal of the water which one of the three mouths of the Rhine discharges in it, and has been filling it up with alluvium so as to make it more and more unfit for navigation.

The Rhine has the advantage of being navigable the whole year round, except when blocked up with ice in winter. Having among its principal sources of supply the glaciers of the Alps in Switzerland, and a large lake (the Bodensee) as a reservoir, deficiency of water for navigation is rare. The water from the melting glaciers is enriched by the soil derived from the erosive action of the continually slowly descending ice crust. This soil is deposited among the bowlders of the moraines through which the water flows, while in addition to this glacial soil the Rhine water gathers more similar material when lower down it winds its way through an extensive and long series of gaps in the Eifel mountains, which are nothing but extinct volcanoes, of which the solidified streams of lava, extending from the old craters obliquely downward to the water's edge, are plainly visible in many directions, and covered with a most luxurious growth of grapevines. The soil washing down from these slopes gives also to the water the most eminent fertilizing qualities, to which Holland owes most of its unrivaled productiveness, especially in milk, butter, cheese, and beef. For the last of these, cattle steamers are daily running from Rotterdam to English ports, so as to import there most of the famous roast beef of old England.

The result of the beautiful situation of Nymegen is that few of its inhabitants leave it in the summer season, except to go to some of the charming villages in its immediate neighborhood. This is mostly done at the time the city is crowded with strangers, among which the English are always very prominent, as they, in their tour up the Rhine, usually are attracted by two specialties, one, which nature has given it, the strikingly lovely scenery, and the other, what man has given it, and which is being carefully preserved, namely, historical monuments in the shape of Roman antiquities, temples, urns containing the ashes of the cremated Roman nobility, statues, old buildings from the middle ages, etc.

In fact, Nymegen is the oldest city in the Netherlands. It has a very interesting history, which reason alone would be sufficient to select it as a residence to be educated in. It is there that the young student finds history all around him, and cannot help to be interested in the events which have made the things he sees, to be as they are.

Such a city offers object lessons which make a much deeper and more lasting impression upon the mind than the memorizing of ever so many chapters in books of history. What I remember to have seen there in boyhood—monuments, down from the era that the Romans came there, the chapel of Charles the Great (Charlemagne), built in the year 780, the remnants of the middle ages, the relics of the great reformation, etc.—have always been my landmarks to localize many of the complicated events in the history of European civilization.

(*To be continued.*)

* Socrates, the Athenian philosopher, was, 2,300 years ago, condemned to death by poison, and that for his religious opinions! He was his own executioner by drinking the prescribed potion of water hemlock (*Cicuta virosa*).

† Lavoisier begged the government that his execution might be postponed until he had finished his labors in a most important investigation, with which he was occupied, by means of apparatus he had invented and constructed, and which investigation he knew would lead to new discoveries of great benefit to mankind; but the brutes who had the power in their hands would not listen, and he was hurried to the scaffold at once.

MICROSCOPIC POND LIFE.

HOLDING up one of our store bottles to the light, we see a number of little creatures moving about rapidly with a brisk, jerky kind of motion. We will take out some of them with a dipping tube, and drop them into a watch glass, whence one or more may be transferred to a live box for examination under the microscope. These are some of the Entomostraca, popularly known as "water fleas," not because they are closely related to the too well known domestic pest, but because that name was given to what is, perhaps, the most abundant species, *Daphnia pulex*, the common water flea, by those who first described it, on account of its leaping motion, its red color and the prolonged beak, which was mistaken for an organ of suction.

The Entomostraca belong to the same order, the Crustacea, as the lobster, the crab, and the river crayfish, from which, however, they differ greatly in size and appearance. The species we are going to examine first is the common water flea (Fig. 1). The females

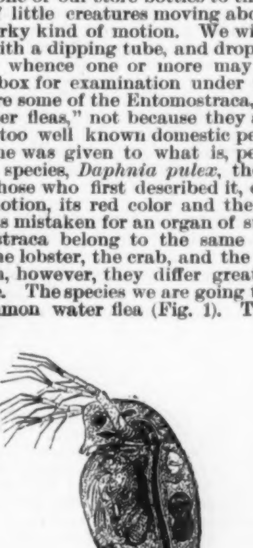


FIG. 1.—*Daphnia pulex* (× 100).

throughout the group preponderate largely over the males, and greatly exceed them in size. As the creature lies gently compressed in the live box, we see that it consists of two distinct parts: the head, which is free and prolonged into a kind of beak, and the body—really the thorax and abdomen—inclosed in a reddish ovate shell, composed of two valves joined at the back and completely open in front. The greater part of the shell is clear and smooth, but in front and in the middle it is marked with fine lines which cross each other. At the lower extremity the valves are produced into a spine set with teeth on the front side. This shell is transparent, so that with the dark ground illumination we can see the internal economy quite plainly. In its early days the animal had two eyes; these, however, have now coalesced to form a single organ of vision, consisting of about twenty crystalline lenses arranged round a central mass of black pigment. The digestive tube can be clearly traced, and the worm-like motion, continually kept up in the intestines of the higher animals also, by which innutritious matter is removed from the body. In the upper half of the space behind this tube the heart is seen pulsating, and just below are two bunches of eggs, and here, if all goes well, they will remain till fully hatched.

One can see the segments or joints of a lobster or crayfish from the outside; one must look inside to see those of a water flea. Though they need a high power and close examination, they are there, nevertheless, eight in number; the first being the largest, and the only one attached to the valves. There are five pairs of feet, not one of which does the animal put to the use for which it is generally supposed feet were intended—progression. They are, however, in constant motion, and their movements drive a stream of water through the valves, thus aiding respiration; and to this work the comb-like branchial plates on the third and fourth pairs largely contribute. The feet also collect food particles from the water, and form them into pellets on which the mandibles may act. The

head bears two pairs of appendages, the inferior and the superior antennæ. The function of the first and larger pair, however, is not that of feelers, for it is by their means that the animal moves through the water; and the form and branching of these organs are used as a means of discriminating species.

Before removing Madam Daphnia from the live box and dropping her into a tank, we will take another look at her fellows swimming about in the store bottle, and endeavor to trace out in them with the hand lens what we have just seen with the miscroscope. Wherever practicable, this is a good plan to adopt.

Next we take another example of the same group, *Cyclops quadricornis*, so named from its four conspicuous antennæ, but popularly spoken of as Cyclops. This little creature is something like a liliputian crayfish deprived of its claws, with its head flattened out, and furnished with a tapering tail. It moves through the water in a series of short darts, scarcely any successive two of which are in the same plane. The head, in the center of which is the single eye (whence the name of the genus, from the Cyclops of classic mythology), is joined to the thorax, in which four segments can be made out, and in the abdomen there are usually six. This form may be easily separated from all other pond crustaceans by the external egg bags, one on each side, near the junction of the abdomen and thorax. These are omitted from Fig. 2, which is contrived to serve a

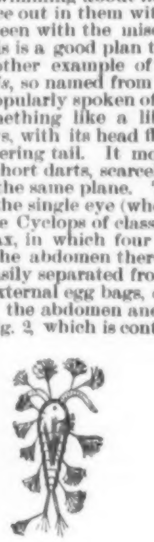


FIG. 2.—*Cyclops* (× 10), showing parasitic growths of *Epistylis anastatica*.

double purpose—to show the form of Cyclops and some of the parasitic Vorticellidans which frequently infest these little animals. If the egg bags are removed from the parent and left in the aquarium under favorable conditions, the young will still be hatched, and on their entrance into the world they are so unlike their mother that early observers placed them in a distinct genus. To the same family as Cyclops belongs the still smaller *Canthocamptus minutus*, which has a single egg bag

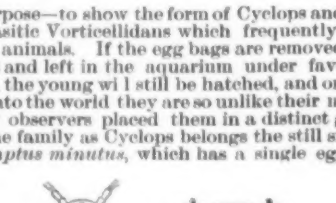


FIG. 3.—A, young of *Cyclops quadricornis;* B, of *Canthocamptus minutus*.

attached to the under side of the body. This form also possesses ten segments, but they taper much more gradually than in Cyclops. At the junction of the fourth and fifth segments the body is very movable, and the animal can bend its tail over its back like a scorpion, or that evil-smelling beetle, *Ocypus olens*, popularly known as the "devil's coach horse."

Diaptomus castor, a larger form, is somewhat rarer. Its generic name refers to its bold flight-like motion through the water, and its specific name was chosen because the naturalist who described it fancied he saw in the large egg bag lying across the abdomen some resemblance to the broad flattened tail of a beaver. In this little animal the distinction between the thorax and abdomen is well marked, and the first segment, in which the large ruby eye is placed, is much the largest. The antennæ are much longer than in any other example of the group, and stand nearly at right angles to the first segment, to which they are attached.

Two other members of the Entomostraca claim a passing notice, Cypris and Candona, "insects with bivalve shells," as Baker called them a century and a half ago in his "Employment for the Microscope." They cannot be mistaken, for their shape differs widely from any of the forms already mentioned. They are about the size of a grain of millet, but the body is inclosed in a more or less oval covering of two valves, somewhat resembling a tiny mussel shell, but joined only in the middle third of the back, where they are connected by a ligament, so that they may be opened or shut at will. The eye is single, and in both genera there are two pairs of antennæ, and the difference in these serves to discriminate the forms. In Cypris the lower pairs are furnished with a pencil of long hairs or filaments, by means of which the little creature swims freely in the water. In Candona these hairs are absent, and the animals can only crawl over the aquatic vegetation or move about on the bottom.

We will now turn to some objects, far more beautiful, but vastly lower in the scale of organization—the bell animalcules. This name was first given to the genus Vorticella, but has been extended in popular

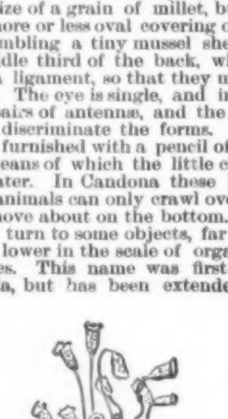


FIG. 4.—*Vorticella nebulifera* (× 50).

phrase to include all, or nearly all, the family. Vorticella, as we know, appears to the naked eye as a delicate film on aquatic vegetation and rootlets. At first sight, under a low power (say one inch), we see that the edges of the leaf and stem which we have placed in the trough are studded with a number of bell or cup-shaped objects, each mounted on a stalk, which continually contracts and extends with a spiral motion. This is effected by means of the *axial fiber*, an elastic thread which runs down the stalk. We can perceive the play of the cilia round the rim, and notice the optical illusion which makes their successive contraction in the same direction resemble the revolution of a toothed wheel. Close inspection will enable us to make out the vortex created by these movements, and if we watch we shall probably see food particles taken in. But a higher power is necessary to give us some idea of the structure of these creatures. We will carefully detach a likely looking leaf from the weed, and lay it on a plain glass slide, adding a drop of water, and placing a cover glass over the whole. If now we substitute a quarter inch or one-fifth inch objective for the one inch, we shall discover that the bell or cup is not such a simple affair as it seemed at first sight. We saw before that it was fixed by its smaller end to the top of the stalk; now we can make out that its upper end is thickened so as to form a rim, which is called the *peristome* (Fig. 5, *p*) or region round the mouth.

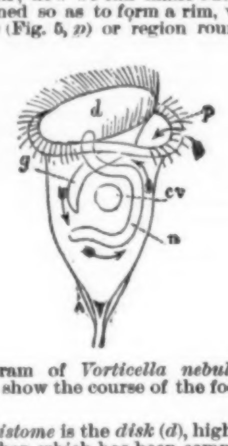


FIG. 5.—Diagram of *Vorticella nebulifera* (× 400). (The arrows show the course of the food particles.)

Inside the *peristome* is the *disk* (*d*), higher on one side than on the other, which has been compared to "a circle of cardboard fitted into a breakfast cup." The mouth (marked by the curved arrow on the peristome) is formed by a depression between the rim and the raised side of the disk, and leads into a conical gullet. The cilia form a spiral wreath, running round the inner border of the peristome, continued on the right into the gullet (*g*) and on the left encircling the disk. But though Vorticella has a mouth and a gullet by which it can take in food, it has no stomach wherein to bestow it. Where, then, does the food go? Into the body mass. Each particle is surrounded by a tiny globule of water, which with its contents, when ingested, forms a bubble called a *food vacuole*, and such food vacuoles circulate in the inner protoplasm till they are absorbed, while particles incapable of absorption are got rid of at the base of the gullet, and swept out of the mouth by returning currents. The *nucleus* (*n*) is really nothing more than a denser portion of the protoplasm inclosed in an extremely delicate membrane.

The *contractile vacuole* (*c v*) is a clear round or nearly round space, which contains a watery fluid. This vacuole periodically disappears with a sudden contraction, and then slowly reappears, reminding the microscopist of the beating of a minute colorless heart.

Reproduction is effected by fission—the splitting up of one individual into two, the one given off being for a time free-swimming. It seems, however, that this process cannot be carried on indefinitely, and rejuvenescence, or the renewal of the capacity to multiply in this fashion, is accomplished by the union of two dissimilar individuals.

We shall probably find, dotted here and there on the film-covered weed, a Vorticella-like animalcule with a body $\frac{1}{400}$ inch long, fixed on a rigid stalk or column about a quarter the length of the body. This will be one of the species of Rhabdostyla, probably *R. ovum*, and a knowledge of this, as well as of the preceding genus, is necessary to enable us to understand how the compound forms, Carchesium and Zoothamnium, Epistylis and Opercularia, developed.

We have seen that the fission of Vorticella resulted in one stalked and one free-swimming form. After a short period of independent existence the latter may develop a stalk and become fixed, or may rejuvenate the race by conjugation. But suppose that the fission were continued down the stalk; we should have a stem giving off two branches, each ending in a Vorticella-like individual. And if the process were continued again and again, the result would be a tree-like colony, with numerous branches, each bearing at its extremity the normal cup-like body of Vorticella.

Now we do find three forms of tree-like colonies, which fall naturally into two groups, one derived from Vorticella, the other from Rhabdostyla. The first group consists of the genera Carchesium and Zoothamnium, compared by Saville Kent to a wall and a standard tree respectively, and from one-sixth inch to one-quarter inch in height, therefore plainly visible to the naked eye.

In Carchesium the axial fiber is discontinuous, each animalcule and each branch contracting and expanding independently of all the rest; in Zoothamnium it is continuous, so that the whole colony is affected by the movement of a single unit—if one contracts, the rest do so simultaneously. In both these forms the main stem is contractile, like the stalk of Vorticella, and the whole colony can subside into a mulberry-like mass. In Epistylis the stalk is rigid like that of Rhabdostyla, and the individual units contract and expand from the point where the stalk joins the main body. The animalcules themselves in all these colonies correspond in structure with Vorticella. One species of Epistylis (*E. flavicans*) often occurs in round masses—sometimes, it is said, as large as a nut—and settles on the sides of aquaria to such an extent as to coat them with "a gray felty mass." I have repeatedly seen colonies as large as a pea, and at the time of writing one of my tanks has at least fifty patches on its inner surface. The genus Opercularia closely resembles Epistylis, but differs therefrom in having the disk capable of elevation to some distance above the rim of the cup, so as to form a kind of lid or cover. We shall probably also find the following solitary members of the same family: Vaginicola, inhabiting a cylindrical glassy sheath; Thuricola, which has this sheath closed at the top with a valve-like apparatus when the animal contracts; Cothurnia, with a bulging vase-shaped dwelling; and Platycola, whose habitation, generally bent into a kind of neck, is always attached on the whole of one side to the leaf or host on which the tiny animal lives. All these forms may be found on water weed, aquatic insects, and Entomostracans (Fig. 2).

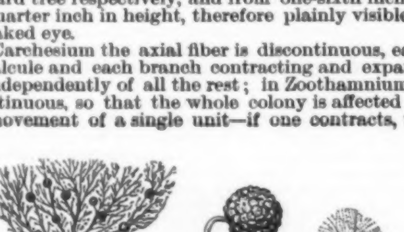


FIG. 6.—1. *Zoothamnium arbuscula*, natural size. 2. The same expanded × 10. 3. The same, contracting × 10. 4. *Carchesium polypinum* (natural size and × 4).

If we find a roundish, green, gelatinous body floating about or attached to some of the weed in a store bottle, we shall have the colonial Vorticellidan *Ophyrdium versatile*, which lives indifferently in fresh and salt water. It is fairly plentiful in one of the ponds in Richmond Park, and may often be met with, usually free, as large as a cherry. If examined with a hand lens, it will be seen that the surface is not smooth; and from time to time minute Vorticella-like animals will protrude at different points of the circumference. After this has been studied, and acquaintance made with the general form of the colony, and the fact fully grasped that it consists of hundreds of individuals, the mass should be dropped into a watch glass full of water, and a strip cut from it with a sharp pair of scissors. This should be placed in a very thin trough, or on a slide under a cover glass. The plan of the colony will then be apparent. Each animal has a separate contractile foot stalk, so that, independently of all the rest, it can come out to seek for food or retire into the central gelatinous mass. This independent movement is like that of Epistylis, and the footstalks of all the members of the colony are joined to a central footstalk, which reaches each after a succession of branchings (thus Y, each arm again giving rise to two

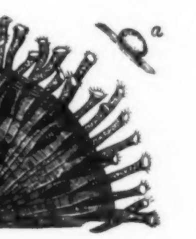


FIG. 7.—*Ophrydium eichhornii* (× 50). After Saville Kent. *a*, natural size.

branches, and so on). The length of one of the extended bodies is from one-eightieth to one thirty-fifth of an inch. When thus examined some of the individuals will probably become detached from the matrix and swim about freely in the trough or under the cover glass. Another form frequently met with is *O. eichhornii* (Fig. 7), which is much smaller, and in which the gelatinous matrix is quite transparent. The footstalk of each individual is carried directly down to the center without branching, so that the two forms cannot possibly be confused with each other.

The genus Stentor contains the trumpet or funnel animalcules, so named from their shape, which, in some species, is not unlike that of an old posthorn. Some are usually adherent to weeds by the narrow end of the body, occasionally swimming off from their resting place by means of the fine cilia with which the body is covered, while others never settle down. Trembley, so well known for his researches on the Hydra, was the first to record this group, and described them under the title "Funnel-like Polyps" in the "Philosophical Transactions" for 1744, for he considered them closely related to Hydra, as apparently did Linne, who put both in the same genus. Trembley described three varieties, which are now recognized as distinct species. The largest, and probably one of the commonest species, is *Stentor polymorphus* (Fig. 8),

FIG. 8.—*Stentor polymorphus* (× 20).

which, when fully expanded, is one-twentieth of an inch long, contracting to about one-sixth that size. It is usually green in color, owing to the presence of chlorophyl granules in the outer layer. The plan of the animal may be compared to that of the cup of Vorticella, elongated and tapering in shape, endowed with the power of contraction and expansion, but possessing no disk. The opening into the mouth corresponds roughly to the bell of the trumpet or the top of the funnel, whence the creature derives its popular names. The curve, however, is a spiral, not a circle, the right hand limb being generally higher than the left. This curve is fringed with cilia, which act in a similar way to those surrounding the cup of Vorticella. This species is found in standing water, on green and decayed vegetation, and generally secretes for itself a

mucilaginous sheath, into which the body can be retracted. Commonly, each sheath is tenanted by a single individual, but these stentors seem to have the social habit, and colonies are occasionally found inhabiting a matrix something like that of Ophrydium in substance, though not in shape. Such a colony is figured by Saville Kent, who found it on the rootlets of Anacharis in an aquarium in 1871, and he appears to have been the first to put such a fact on record. One word of caution is necessary here; the large size of *Stentor polymorphus* has sometimes caused it to be mistaken by beginners for some of the tube-dwelling Rotifers; but its spiral ciliary wreath and its low organization should guard us against such an error. Black Stentors (*S. niger*) are much smaller, always free-swimming, extremely changeable in shape, and when fully extended about three times as long as broad. Kent records it only from bog water on Dartmoor, but in some of the ponds near London it is very abundant, and in some of the ponds in Epping Forest it is said that these animalcules swarmed to such an extent as to give an ordinary observer the idea that the water was discolored by a shower of "blacks."

The two little animals that we will look at next have long, high-sounding, scientific names—*Actinophrys sol* and *Actinosphærium eichhornii*—but are popularly

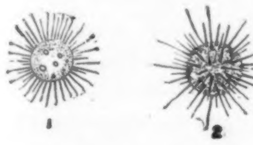


FIG. 9.—1. *Actinophrys sol* (× 100). 2. *Actinosphærium eichhornii* (× 30).

spoken of as sun animalcules, from the fact that they somewhat resemble the "sun in his splendor," as figured by heralds and painters of tavern signs. The latter is the rarer and much the larger of the two, and shows a slightly higher stage of development. The former may be found in almost every pond or lake, swimming among aquatic plants, its favorite haunts being duckweed, hornwort, bladderwort, or the thread-like Algæ. A likely place to find Actinosphærium is among the fibrous rootlets of willows and alders. A piece of willow root some six inches long, recently taken near London, when placed in a small window aquarium for examination, was found to have at least a score of these tiny creatures on it. Each consists of a tiny speck of protoplasm, from which radiate long thread-like processes, generally motionless, except when engaged in the capture of prey. These animals are very low in the scale of living creatures—just one stage above the Amœbas, which are described by Dr. Hudson as "slow gliding lumps of jelly that thrust a shapeless hand out where they will, and, grasping their prey with these chance limbs, wrap themselves round their food to get a meal; for they creep without feet, seize without hands, eat without mouths, and digest without stomachs." No sooner does a luckless water flea, infusorian, or tiny rotifer come in contact with the thread-like rays of a sun animalcule, than it is at once held firmly, and the thread begins to contract, while its fellows near bend round to lend their aid, and so the captive is slowly but surely drawn down and engulfed in the living mass which rises to meet it. The voracity of these animals is out of all proportion to their size. One observer saw an Actinosphærium one-thirtieth of an inch in diameter that had ingested a couple of Entomostraca, a few rotifers and infusorians, and a quantity of the spores of Algæ, so that, in his own words, "the object on the slide appeared about one-third Actinosphærium and two-thirds dinner."

Besides the difference in size—and Actinophrys is rarely more than one hundredth of an inch in diameter—it will be seen that there is a difference in their structure. In Actinosphærium the protoplasm is differentiated into an interior and clouded and an exterior and clear portion, which surrounds the other like a ring. The rays of Actinosphærium are more distinctly stiffened with a kind of internal axis, though in both forms these rays can be retracted, and sometimes they are wholly withdrawn into the central mass. When either of these forms is in the zoophyte trough, some Entomostraca may be introduced, and the process of feeding may be watched at leisure. In these low forms reproduction by fission may be advantageously studied. First of all, the nucleus—which is found in all the Protozoa—is elongated, and then gradually constricted in the middle till it divides, one part of the body mass flowing round one nucleus and the rest round the other, so that, when this process is complete, we have two individuals where a moment before there was only one, and the parent form has ceased to exist. This method of reproduction has led Professor Weismann to the conclusion that none of these one-celled creatures can die a natural death. The theory is extremely interesting, and those who care to pursue the subject will find it discussed in Dr. St. George Mivart's recently published "Essays and Criticisms." The observer should take as little as possible on trust, and should endeavor to verify every statement by actual ocular demonstration. By this means facts will be firmly impressed on the memory, and habits of observation will be formed which cannot fail to be attended with beneficial results.

Our store bottles contain a good many free-swimming Infusoria, but in order to take out a few of them we must have recourse to stratagem. Selecting a bottle in which these minute forms of life are plentiful, we will place it where the ray from the lamp may fall full upon it, for though these little creatures have no sense organs in any way analogous to those of higher forms, yet in some way they are influenced by light. Now we will take a card, and, having cut out from about the middle a roundish patch as large as a shilling, lay it against the bottle so that the direct rays shall only enter through that hole. And, just as fish will crowd to a hole in the ice for air, so will these animalcules swarm to the light, and consequently they may be taken out without much trouble by means of a dipping tube or pipette.

The first that comes to hand is *Coleps hirtus* (Fig. 10), fairly common in pond water, among duckweed and other vegetation. It has been called the barrel animalcule from its shape, and as it goes on rolling over and over on its longer axis across the field of vision, it will be confessed that the name is by no means inappropriate. It is a wonderfully active creature, perpetually in motion, and an admirable scavenger, for there seem to be no limits to its capacity for assimilating dead and decaying organic matter. Saville Kent remarks that a crushed Entomostracan, or any

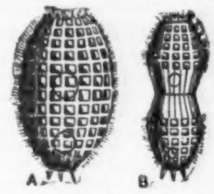


FIG. 10.—*Coleps hirtus* (×400). After Saville Kent. A, adult; B, example dividing by transverse fission.

other creature that has met a violent or natural death in water abounding with this animalcule, "is quickly surrounded and devoured with an amount of happy dispatch that, comparing small things with great, would scarcely disgrace a troop of jackals collected around some desert carrion." So that, small as they are, these creatures perform an important function in the economy of nature by purifying the water in which they live.

We shall also be pretty sure to meet with *Trachelocerca olor*, for it is very common, and if any are present, we shall certainly find two, for they hunt in couples. It is generally found in pond water, among decaying vegetation, or on thread-like Algæ. This is one of the earliest known forms, and was called the "Proteus" by Baker, who was the first to figure it, in 1752. Its general form and structure may be made out from the illustration (Fig. 11), and it will be noted that

FIG. 11.—A, B, *Trachelocerca olor* (× 300).

the specific name, which means "swan," is particularly appropriate, though Kent considers that this little creature suggests the restored figures of the extinct Plesiosaurus. To the writer, however, this Infusorian—with a name as long as its neck—always suggests a swan, and when it is seen thrusting this long neck among the flocculent vegetable debris on which it feeds, one can almost fancy he is looking at a tiny swan searching the bottom of some ornamental water for its food.

There is one other form to be mentioned—*Amphileptus gigas;* but though it is much larger than the "long-necked swan"—for it is sometimes found one-sixteenth of an inch in length—there is so much similarity between them that it only requires a few words of description. Its mouth is situated at the base of the neck, which serves as a proboscis, with which food is collected and conveyed to the proper receptacle. No words, however, can convey more than a faint idea of the extraordinary pranks Amphileptus plays with this proboscis. Not only is it turned this way and that way in search of provender; it is alternately contracted and extended, and wreathed about the creature's body in fantastic shapes, just as one may see flamingoes do before settling to sleep.

Our last dip brings out Volvox, one of the most charming objects known to microscopists, and one that has had a checkered existence—in books. Ehrenberg classed it among his Infusoria; then the botanists claimed it, and it was put among the Algæ; and under this heading a detailed description of it will be found in most popular books. But the highest authorities, German and English—Stein, Butschli, and Lankester—agree in classing Volvox with the Flagellate Infusoria—in other words, among animals. But before we freely examine the Volvox, we will look at a simple form which will help us somewhat to understand the more complex.

Euglena viridis (Fig. 12) is a good example of an

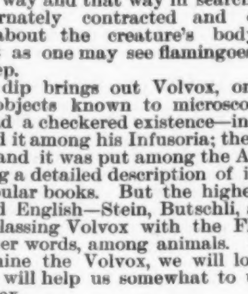


FIG. 12.—*Euglena viridis* (× 350).

Infusorian furnished with a *flagellum*, or whip-like filament, which serves as a swimming organ. This little animal is a minute speck of bright green protoplasm. It is normally spindle-shaped, but undergoes many changes of form, which, however, principally affect the center of the body mass, for the two extremities always remain more or less pointed, as shown in the illustration. From what is by courtesy called the head the flagellum projects, and at its base is a minute aperture serving as a mouth and leading into a gullet, which is soon lost in the body mass. Just at one side of the mouth is a minute red dot commonly called the "eye spot," though it is certain that the name is misapplied. These animals are sometimes so numerous as to tinge with green the water in which they are found, and they are often met covering stagnant pools with a floating surface of green, which, when collected on paper, will preserve its color for a long time. According to Prof. E. Ray Lankester, species of Euglena formed the "green matter" from which Priestley obtained oxygen gas. Euglena is, however, most important from our point of view as being closely related to the component parts of the compound form.

Volvox globator (Fig. 13) is globular in form, and fifty of them placed side by side would measure about

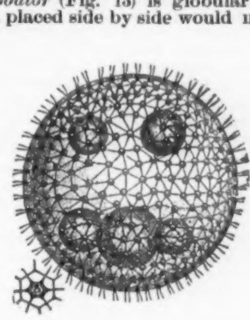


FIG. 13.—*Volvox globator* (× 75).

an inch. It is common in many clear ponds round London, and on the Hertfordshire border I have taken it in such quantities that the two ounce dipping bottle when held up to the light was quite colored with the "light green crystal spheres sailing slowly along like planets revolving through space." Each sphere, however, is not a simple animal, but a colony made up of a number of euglena-like zooids, or individuals capable of independent existence. This will be better understood from the illustration, where these individuals will be seen as tiny circles on the surface of the sphere which directly meets the eye, and round the edge the two flagella with which each is furnished may be seen. A high power will reveal the fact that each zooid is the center of a hexagon, and connected with its neighbors by minute threads of protoplasm, so that the whole mass is bound together by a living net work, the interstices of which are filled with a transparent substance. Here, then, we have a hollow sphere, composed of a multitude of individuals, and by the motion of the flagella with which each individual is furnished the colony revolves. This sphere is filled with liquid, in which similar but smaller spheres may often be seen revolving. These are built up on precisely the same lines as the parent sphere in which they are inclosed, and furnish a strong argument for the animal nature of the organism, for such a method of reproduction is certainly not plant-like. When the organism has been examined as a whole, and made out point by point, one should be placed under a cover glass or compressed in a live box so as to burst the sphere, and under a high power the zooids will be seen swimming in different directions, affording incontestable proof of the colonial nature of Volvox.—*Leisure Hour.*

PERCENTAGE SOLUTIONS.*

By CHAS. CASPARI, Jr.

ALTHOUGH this subject has been treated by several writers during the past fifteen months, some confusion seems still to exist in the minds of many pharmacists as to the proper plan for preparing small quantities of percentage solutions at the dispensing counter. The cause, apparently, lies in the fact that pharmacists imagine, when a physician orders 2 or 4 fluid drachms of a 4 per cent. cocaine solution or a 1 per cent. mercuric chloride solution, they must prepare exactly that quantity, neither more nor less, and at the same time forget that the percentage of medicinal agent present forms a part of the whole quantity of solution ordered. The writer has had occasion several times to correct physicians as well as pharmacists when they claimed that 4 grains of any salt dissolved in 100 grains of water would produce a 4 per cent. solution. (Four grains of the salt to 100 minims of water would be more nearly correct, as 100 minims of water weigh practically 95 grains.) It is pretty well understood the world over that in the case of solutions of solids and gases in liquids the percentages are calculated invariably by weight of solvent and dissolved body, but in the case of solution of liquids in other liquids the percentages may be calculated *either by weight or volume*, and it becomes necessary to specify which of the two is intended. As examples of the first class may be mentioned cocaine hydrochloride solution, mercuric chloride solution, oleate of quinine, oleate of veratrine, chlorine water, ammonia water, etc., whereas the official alcohol and diluted alcohol offer striking examples of the class of solutions of liquids in other liquids. The U. S. Ph. specifically states of official alcohol that it shall contain 91 per cent. by weight (94 per cent. by volume) of ethyl alcohol and 9 per cent. by weight (6 per cent. by volume) of water, showing that the percentage of absolute alcohol present may be reckoned either by weight or volume.

For the pharmacist it is surely the simplest and by far the safest plan to make percentage solutions of salts according to one fixed rule by weight, choosing the quantities nearest to the desired volume, even if the operation entail a slight loss, rather than aim at producing the exact volume wanted by using fractions almost unweighable on his prescription balance. For instance, we know that distilled water at 60° F. is assumed to weigh practically 456 grains (U. S. Ph. 455·7 grains) per fluid ounce, and this can be our guide in determining the proper proportions for a solution. As an example, take a 2 per cent. solution of any soluble chemical; to have two fluid drachms of this solution, we would take 2½ grains of the chemical and 122½ grains of distilled water, and to have 4 fluid drachms of a 4 per cent. solution, we would take 10 grains of the chemical and 240 grains of distilled water; in either case our finished solution would be slightly more in

* From the *Pharmaceutical Review*, May, 1892.

volume than needed, and this trifling excess could be thrown away. If larger volumes are to be prepared, a closer calculation could be made, so as to avoid possible waste of expensive material. For instance, if 8 fluid ounces of a 5 per cent. solution of cocaine hydrochloride are wanted, we should say 8 fluid ounces of water will weigh 3,648 grains; hence we shall make a quantity of solution nearest to it in weight and yet insure our volume. This we find to be 3,850 grains, and of this weight 5 per cent. is 192½ grains; we must therefore use 192½ grains of the cocaine salt and 3,657½ grains of water, yielding a trifle over 8 fluid ounces of solution. If two or three substances are to be present in a percentage solution, their combined weights must be subtracted from the desired weight of the finished product, in order to find the proper quantity by weight to be used of the solvent. For instance, a physician desires 1 fluid ounce of a 4 per cent. cocaine solution containing 2 per cent. of boric acid: the quickest way to make it would be to dissolve 20 grains cocaine hydrochloride and 10 grains of boric acid in 470 grains distilled water, and of this solution measure 1 fluid ounce; the excess of volume would be found very trifling.

If a percentage solution is to be reduced to a lower percentage strength, a very simple rule can be applied, namely, multiply the required quantity by the required percentage and divide the product by the given percentage; the quotient will be the quantity of the stronger solution necessary to yield the weaker solution and the difference between the quantity thus found and the required quantity of weaker solution represents the necessary quantity of diluent to be used, which may be water or such other solvent as the stronger solution was made with. This rule can be used equally well for percentage solutions made by weight or volume, as the case may be. For instance, wanted 1 troy ounce (480 grains) of ½ per cent. mercuric chloride solution to be made from a 2 per cent. solution already on hand; then $480 \times \frac{1}{2} = 240$ and $240 \div 2 = 120$; hence we would take 120 grains of the 2 per cent. solution and add 360 grains of water. Again, wanted ½ gallon (64 fluid ounces) of dilute alcohol, U. S. Ph., to be made from alcohol on hand containing 92 per cent. by volume. Official dilute alcohol contains 53 per cent. by volume of absolute alcohol; then $64 \times 53 = 3392$, and $3392 \div 92 = 36{\cdot}87$; hence we must take 36·87 fluid ounces of our 92 per cent. alcohol and add sufficient water to yield 64 fluid ounces.

The fact that many solids increase the volume of the solvent when brought into solution by the same may be left out of consideration entirely by the pharmacist in the preparation of percentage solutions, except when large quantities of strong solutions are to be made and the required quantity be expressed in volumes.

Above everything, let the pharmacist remember that percentage solutions of solids should always be calculated by weight, and that the percentage expresses the number of parts of the solid necessary to make 100 parts of the solution, and this number subtracted from 100 leaves the requisite number of parts by weight of the solvent to be used.

MOLYBDIC ACID AS A COLOR REAGENT FOR CERTAIN AROMATIC OXY-COMPOUNDS.

By J. STAHL.

HAGER some time ago indicated a reaction for the tannic acid of galls and other tannic acids, according to which these substances give fine reddish yellow colors with ammonium molybdate. I have found that the same reactions occur for certain compounds approximating on tannin, pyrogallol, pyrogallo-carbonic acid, and gallic acid. As all four substances named contain oxy-groups in an ortho-position to each other, the reagent was tried also for other aromatic compounds in which the same case occurs. The result was that ammonium molybdate is a specific color reagent for all aromatic compounds which contain two or more oxy-groups standing in the ortho-position to each other.

Ammonium molybdate produces intense phenomena of coloration only with such bodies, which, according to the substance employed, may be yellow, reddish brown, or blackish brown. On the contrary, in all organic compounds in which the above mentioned condition does not occur, no coloration is recognized. Thus, with pyro-catechin on the addition of the molybdate there is shown an intense reddish brown color, which does not appear with hydroquinone and resorcin, a behavior which shows phloroglucine in contrast to pyrogallol. The following aromatic compounds display similar colorations: Protocatechuic acid, caffeic and hydrocaffeic acid, phenanthrenehydroquinone, and retenehydroquinone; in alizarin, purpurin, anthragallol, and rufigallic acid, the aqueous solutions of which are yellow or red, the tone is much intensified by an addition of the molybdate. The entrance of other groups into the nucleus does not generally interfere; thus the reaction appears in the bromo and nitro derivatives of pyrogallol and gallic acid, but not in the phenol ethers, where one or more hydrogen atoms of the oxy-group are replaced by alkyles, as guaiacol and vanilline. Very slight yellow colorations which may occur with the two last mentioned bodies are probably due to slight impurities. Among compounds of a less fully known constitution the reaction is produced by quercitrin and its scission product quercetin, apomorphin, podophyllin, koussein, and aloin.

The aqueous solution of free molybdic acid behaves exactly like ammonium molybdate. The latter, in presence of organic substances, passes to a lower stage of oxidation, with the production of a blue, yellow, or a reddish brown.

The origin of the color phenomena in question depends on the oxidizing action of molybdic acid and its ammonium salt. As those aromatic compounds which contain oxy-groups in the ortho-position to each other are more unstable and especially more readily oxidizable than their isomers, there occurs here a more energetic reduction of the molybdic compounds. The stage of the blue oxide is overleaped, and there appear at once the lower brownish stages of oxidation. If heat is applied and the reaction is prolonged, brownish black masses separate out which are found to be a variable mixture of lower molybdic acids, while a portion of the organic substance is oxidized to carbonic acid and water. But it is not impossible that there may appear simultaneously yellow or brown oxidation products of the oxy-compounds.

The sensitiveness of these reactions is not very great, but in case of pyrocatechin, pyrogallol, gallic acid and tannin it admits of the recognition of 0·1 mgrm. substance in 1 c. c. of liquid. The action of sodium tungstate is similar to that of ammonium molybdate.—*Ber. Deuts. Chem. Gesell.; Chem. News.*

POISONOUS PROPERTIES OF MELAMPYRUM.

WHILE investigating the cause of the sudden death of a valuable ram imported into Hungary from England, K. Czako found in the stomach and intestines immense quantities of the seeds of *Melampyrum sylvaticum*, to which the death was apparently due. The seeds of this species and of *M. arvense* contain melampyrite $C_{12}H_{14}O_{12}$ and rhinanthine $C_{29}H_{52}O_{20}$. Experiments on mice and hares showed that the seeds of these and of two other species of *Melampyrum* produced toxic effects, and established that the poisonous principle is the rhinanthine. This substance is, however, formed only in the ripe seeds, and the plants furnish a valuable food for cattle up to the period of flowering. When, however, the seeds are ripe, or nearly so, they must be carefully avoided (Allategeszsegugyi Evkonyo, 1889; see *Bot. Centralblatt*, 1892, Beikefte, p. 65).

THE

Scientific American Supplement.

PUBLISHED WEEKLY.

Terms of Subscription, $5 a Year.

Sent by mail, postage prepaid, to subscribers in any part of the United States or Canada. Six dollars a year, sent, prepaid, to any foreign country.

All the back numbers of THE SUPPLEMENT, from the commencement, January 1, 1876, can be had. Price, 10 cents each.

All the back volumes of THE SUPPLEMENT can likewise be supplied. Two volumes are issued yearly. Price of each volume, $2.50 stitched in paper, or $3.50 bound in stiff covers.

COMBINED RATES.—One copy of SCIENTIFIC AMERICAN and one copy of SCIENTIFIC AMERICAN SUPPLEMENT, one year, postpaid, $7.00.

A liberal discount to booksellers, news agents, and canvassers.

MUNN & CO., Publishers,
361 Broadway, New York, N. Y.

TABLE OF CONTENTS.